3-1977

Estimated impacts of two environmental alternatives in agriculture: a quadratic programming analysis

Center for Agricultural and Rural Development, Iowa State University

Kent D. Olson
Iowa State University

Earl O. Heady
Iowa State University

Carl C. Chen
Iowa State University

Anton D. Meister
Iowa State University

ESTIMATED IMPACTS OF TWO ENVIRONMENTAL ALTERNATIVES IN AGRICULTURE: A QUADRATIC PROGRAMMING ANALYSIS

CARD Report 72

THE CENTER FOR
AGRICULTURAL AND RURAL DEVELOPMENT
IOWA STATE UNIVERSITY, AMES, IOWA 50011

ESTIMATED IMPACTS OF TWO ENVIRONMENTAL ALTERNATIVES IN AGRICULTURE: A QUADRATIC PROGRAMMING ANALYSIS

by

Kent D. Olson

Earl O. Heady

Carl C. Chen

Anton D. Meister

This research study was completed under a grant from the RANN Program (Research Applied to National Needs) of the National Science Foundation (GI-32990). Any opinions, findings, conclusions, or recommendations expressed in this paper are those of the authors and do not necessarily reflect the view of NSF.

CARD Report 72

The Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50010

March 1977

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Page

I. INTRODUCTION

This is one of several Center for Agricultural and Rural Development (CARD) studies that pertain to land and water use and environmental policy. Previous studies have emphasized soil loss control (Nicol, Heady, and Madsen, 1974), environmental enhancement and export levels (Meister, Heady, Nicol, and Strohbehn, 1976), sedimentation limits (Wade and Heady, 1976), and impacts when land use policies are applied in one state but not nationally (Nagadevara, Heady, and Nicol, 1975). The foregoing studies have been made with a range of linear programming models. The purpose of this study is to evaluate impacts for 1980 of two potential environmental controls; this evaluation is made by an interregional quadratic programming model.

These potential environmental controls are assumed to be implemented on a national scale by possible government policies. One policy alternative limits the rate of nitrogen fertilization in U.S. agriculture. A second policy alternative removes four organochlorine insecticides from the market. The two alternatives imply a free market except for restrictions on the use of nitrogen fertilizer and the specified insecticides. The effect of these policy alternatives are compared with a base alternative that does not have restrictions on fertilizer and insecticide use. All three alternatives include (a) normal or trend export levels and (b) <u>no</u> supply control or price support programs. The effects of each alternative on interregional production patterns, land use, commodity prices, consumer food costs, and related items are evaluated.

Nitrogen fertilizer and organochlorine insecticides are considered problem pollutants when they stray from the initial application site. Nitrogen fertilizer may be carried to water in two main forms. The nitrate ion can be leached by sufficient amounts of percolating water. The ammonium ion attaches itself to soil particles and is carried away if the soil is.

The concentration of the nitrate ion in water is of concern for humans. The disease infant methemoglobinemia is caused by water nitrates. Hogs and cattle exhibit poor growth characteristics with nitrates in their water. Gastroenteritis, diarrhea, and even death can occur with high nitrate levels.

One point should be mentioned here: Nutrient runoff is considered an external benefit by some people in that it promotes water plant growth which promotes fish production. But negative marginal returns in this area are still possible at some level of runoff.

With insecticides, the problem is persistence; unless a heavy rainfall occurs shortly after field application, often less than 5 percent of the pesticide application is lost by erosion (Stewart, 1975, p. 45). Organochlorine insecticides have the longest half-life or persistence of the pesticides and thus, pose an environmental problem. Persistence causes problems due to higher concentrations in higher levels of the food chain.

Milk has higher levels of organochlorine insecticides than the plants which the cow ate. Tuna and other fish have higher levels than the fish and plants that they eat which receive organochlorines from inland water. For humans this means that as we eat food with organochlorine insecticides, the insecticide may build up to unprecedented levels in our bodies.

Because these chemicals have been with us such a short time, we do now know what this gradual build-up will do to our bodies. We do know that high levels acquired in a short time will cause sickness or even death, but the effects of a gradual build-up are unknown.

This study does not intend to prove or disprove these concerns, but it is intended to show economic impacts of governmental policies which might be used to alleviate these potential problems.

Although nitrogen fertilizer and organochlorine insecticides are not the only concerns for agriculture, this study is narrowed in scope so that its results will be comprehendable. For any other problems, the micro-economic effects of possible environmental policies should be determined and then the macroeconomic effects can be easily analyzed using the quadratic programming model described later in this report.

Chapters IV and V report the results of possible policy alternatives of nitrogen fertilizer and insecticide restrictions, respectively. Chapter VI summarizes the results and presents conclusions concerning the impacts of these policy alternatives. Before the results are given, the theory of quadratic programming and its application to agriculture is explained in Chapter II. The base model used in this report is described in Chapter III.

II. QUADRATIC PROGRAMMING AND COMPETITIVE EQUILIBRIUM IN AGRICULTURE

Linear programming (LP) has been used widely in economic analysis of spatial and(or) time allocation of goods and resources and other problems. Algorithms exist which, if given correct data, will converge readily to an optimal solution. LP is primarily used to find optimal quantities but, aside from shadow prices, data regarding prices of these quantities are exogenous to the model. For an individual in a perfectly competitive economy, prices are given from the "outside," hence, LP gives him a reasonable solution. But for aggregative quantities, demand functions slope downward and a method is needed to determine both prices and quantities endogenously and in relation to each other.

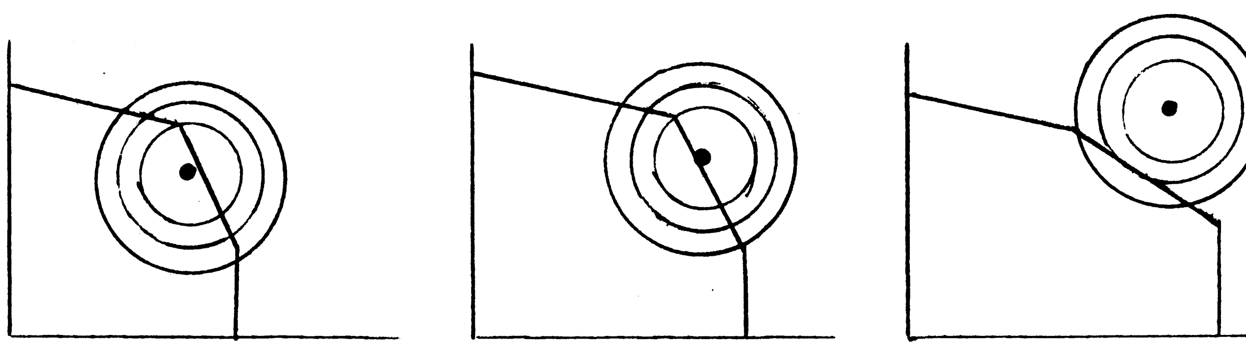
Nonlinear programming (NLP) in most cases can reflect real world situations better than a linear programming model. In addition to conventional linear problems, discountinuities, sloping demand curves, nonconstant returns-to-scale, and other nonlinear problems can be easily incorporated into an NLP model. Because of larger, cumbersome mathematical algorithms, few NLP models have been built and solved. When NLP algorithms are used, we often have no prior knowledge that an optimal solution will be reached or that the solution will be a global solution.

Quadratic programming--a hybrid of linear and nonlinear programming models--has several efficient algorithms associated with it. Quadratic programming (QP) is so named because of its ability to optimize an objective function containing both linear and quadratic terms subject to linear constraints. It is not completely NLP, but QP goes farther than LP in its ability to determine endogenously both prices and quantities of agricultural goods. However, QP still has the restriction of constant returns to scale (i.e., the constraint matrix must be linear).

Figure 1 shows three possible alternatives associated with an optimal solution in quadratic programming. Graph A shows a solution within the confines of the constraints, allowing resources and inputs to be reallocated to other production processes. This alternative is not examined extensively because it presents no actual allocation problem except to determine the slack resources. Graphs B and C show more realistic solutions. Not drawn, but it should be mentioned, is the possibility of the solution point occurring at a corner or extreme point of the constraint set, or, analogous to case C, the largest attainable value of the objective function occurring at an extreme point. Dorn (1961) and Cottle and Dantzig (1967) have shown that when solving a QP model with a self-dual objective function, the solution always lies on an extreme point.

Self-Dualism in Quadratic Programming

Defining a primal LP problem as minimization of production costs subject to resource constraints and minimum production levels, the optima will be denoted as $f(\bar{x})$. The dual of this problem is the maximization of gross producer profits subject to the restriction that net profit each activity be zero or negative. (Gross producer profits are used here as the sales of goods minus purchases of resources.) Let the optimal solution of the dual be $g(\bar{w}, \bar{u})$ where w is the vector of imputed prices of the goods and u is the vector of imputed values of resources. From basic linear programming theory we know that if firms face the prices $\bar{w}$ and $\bar{u}$, the quantities $\bar{x}$ will be produced and given quantities $\bar{x}$, prices $\bar{w}$ and $\bar{u}$ will result.



Graph A
solution within the contraint set

Graph B
solution on the production possibility curve

Graph C
solution outside the constraint set

Figure 1. Alternatives for a solution in quadratic programming

Combining the primal and dual problems, the problem is now to maximize net producer profit subject to resource constraints, minimum production levels (i.e., supply ≥ demand), nonpositive pure profit, and the usual nonnegativity constraints, as were assumed above implicity. These constraint equations are skew symmetric, thus making the feasibility space that Tucker (1956) and Goldman and Tucker (1956) refer to as self-dual.

Denoting the optima as $(\bar{x}, \bar{u}, \bar{w})$, it can be shown that these optimal values are the same as those from the primal and dual problems.

In the primal problem the minimum production levels can be considered as levels of demand determined outside the model. In the dual problem the production levels can also be described as the levels of demand. If demand is now described as a linear function of prices (2.1), a quadratic objective function is evident. Letting small letters denote vectors and capital letters denote matrices:

$$d = d_o + Dw \tag{2.1}$$

where

d = total demands at imputed prices;

d_o = given demands (intercepts);

D = a negative semi-definite matrix of linear demand slopes (D is not required to be symmetric); and

w = imputed prices.

Plugging (2.1) into the primal linear problem and using Hanson's (1961) duality theorem, we can obtain a quadratic problem that is self-dual; i.e.;

$$\text{Maximize } \phi\,(x,u,w) = d_o'w + w'Dw - b'u - c'x \tag{2.2}$$

$$\text{subject to } Dw \quad -Ax \le -d_o \tag{2.3}$$

$$Bx \le b \tag{2.4}$$

$$A'w - B'u \le c \tag{2.5}$$

$$w,\ u,\ x \ge 0 \tag{2.6}$$

where d_o, D, and w are as previously defined. A and B are matrices of technical coefficients which describe the transformation of each of the primary resources through the production activities into a set of final quantities demanded. The vector c contains the exogenous costs associated with each of the production activities. The vector b is the available primary resources while u is the value imputed to these resources. Vector x is, of course, the calculated levels of production of the various activities. The constraint matrix is skew symmetric except for the matrix D so we have a quadratic self-dual system.

The objective function (2.2) maximizes net producer profit. Because the restraints put on the model, this net producer profit will be optimal at zero. This is apparent since we know that if MC > MR, no activity will come into the solution, and if MR > MC, the activity can be increased until MR = MC. Constraint (2.5) says that the value of an activity cannot exceed the exogenous cost of that model plus the imputed value of the primary resources used in that activity.

Constraint (2.3) allows supply to be equal to or greater than demand, but not less than demand. Constraint (2.4) puts a limit on the amount of primary resources available. Constraint (2.6) is the normal nonnegativity requirement. Taken together, constraints (2.3) to (2.6) describe the equilibrium conditions in a competitive market.

Optimization of a Self-Dual Quadratic Model

So far the structure of a quadratic self-dual program has been described, but we have not dealt extensively with optimization. Knowledge of the theory of LP optimization is assumed in the presentation. There are many good sources on the theory of quadratic programming so only a brief coverage is given here. For more detail, see Boot (1964), Hadley (1964), Sposito (1975), or Takayama and Judge (1964a and 1971).

Kuhn and Tucker (1951) developed necessary and sufficient conditions which characterize an optimal solution of a quadratic programming problem. Simply, these conditions say that a function of x is at a maximum, $\bar{x}$, (given $\bar{x} \geq 0$) when

$$df(\bar{x})/dx \leq 0 \quad \text{and} \quad \left(df(\bar{x})/dx\right) \cdot x = 0 \tag{2.7}$$

These conditions say that when x is confined to be nonnegative, maximizing f(x) requires either the first derivative of f(x) with respect to x equals zero or x itself be equal to zero (or both may be equal to zero).

When the Kuhn-Tucker conditions are to be applied to a quadratic programming model, the problem is first written in Lagrangean form and the first derivatives taken with respect to both the structural and Lagrangean variables. The structural derivatives are constrained to be nonnegative. Although the necessary conditions state that the product of these derivatives and the respective variables is equal to zero, the sufficient condition states that D must be negative semi-definite.

Using Takayami and Judge's (1964a) formulation of competitive equilibrium, Stoecker (1974) condensed the size of the overall matrix. Takayama and Judge's (T-J) constraint matrix with the Kuhn-Tucker conditions is identical to the initial Stoecker constraint matrix before the

Kuhn-Tucker conditions are applied. Yaron, Plessner, and Heady (1965) showed that "net consumer surplus" maximization cannot be extended to nonsymmetric demand matrices as Takayama and Judge (1964b) emphasized. Unless D is symmetric, the required integration for the T-J problem cannot be done and the objective function is not defined. Since in the T-J problem the search for competitive equilibrium is a search for the price and quantity where supply equals demand, the supply and demand curves can then be expressed as a set of nonexact differential equations and thus D becomes nonsymmetric.

The Lagrangean constraint set, as the above derivatives are called, for the quadratic self-dual is easily determined and is given below.

$$\begin{bmatrix} -d_o \\ b \\ c \end{bmatrix} \geq \begin{bmatrix} D & & -A \\ & & B \\ A' & -B' & \end{bmatrix} \begin{bmatrix} w \\ u \\ x \end{bmatrix}$$

Linear programming has the property that its optimal solution will lie on an extreme point of the constraint set. Self-dual programs are an exception to most nonlinear programs because the optimal solution of a self-dual will always occur on an extreme point of the initial constraint set. Dorn (1961) first noted this for quadratic self-dual systems when the quadratic form was strictly definite. Cottle (1963, 1964, 1966) and Cottle and Dantzig (1967) showed that the optimal extreme point solution held when the quadratic form was also allowed to be semi-definite.

The algorithm presently used to solve quadratic programs is Zorilla by Soults, Zrubek, and Sposito (1969). Zorilla uses the simplex method of solving quadratic systems as designed by van de Panne and Whinston (1965 and 1969).

In this study quadratic programming is used to solve for a competitive equilibrium in agriculture. This method is used because both prices and quantities are determined endogenously. In addition, constraints can be written and introduced that allow zero or negative profit in production. The objective function in this model provides market rates of returns to resources and maximizes profits at the zero level as assumed for a pure competitive equilibrium and prices and quantities are determined simultaneously.

Once built, this model can be changed to reflect the possible effects of the intervention of government, business, and other factors. In this study we look at the effects of two possible government environmental policies; one, a restriction on nitrogen fertilizer use, and second, the removal from the market of four organochlorine insecticides. In Chapter III the mathematical model, the competitive equilibrium conditions, and the data formulation methods of the present, unrestricted national model are presented.

III. A MODEL FOR U.S. AGRICULTURE IN 1980

In the previous chapter the theory of quadratic programming was summarized. The requirements and conditions for optimization are presented as they relate to the aim of this chapter. In this chapter we develop a national quadratic model for U.S. agriculture in the year 1980 and then modify this basic model in subsequent chapters.

This study draws on four previous dissertations: Plessner (1965), Hall (1969), Stoecker (1974), and Chen (1975). Also, several articles serve as a partial basis: Yaron, Plessner, and Heady (1965); Plessner and Heady (1965); Heady and Hall (1968); Hall, Heady, and Plessner (1968); and Hall, Heady, Stoecker, and Sposito (1975).

Assumptions and Definitions

The 48 continental states and the District of Columbia are divided into 10 spatially separated consuming regions (CRs; Figure 2). These 10 consuming regions are further subdivided into 103 producing areas (PAs; Figure 3). The 17 Western states are divided into 10 irrigated crop producing areas (Figure 4).

Crop production is defined on the producing area level and on the irrigated area level. Livestock production is defined on the consuming region level. Producers of a commodity within an area or a region are assumed to be homogenous with respect to technology. The crop and livestock production activities constitute a constant technology matrix and these activities are technologically independent.

Commodities used in, or produced by, activities are classified according to their use. These classes are primary, intermediate, and final (or desired) commodities. The commodities in this model are listed by these classes in Table 1.

Transportation is defined between the 10 consuming regions for specific final and intermediate commodities. It is assumed that corn, oats,

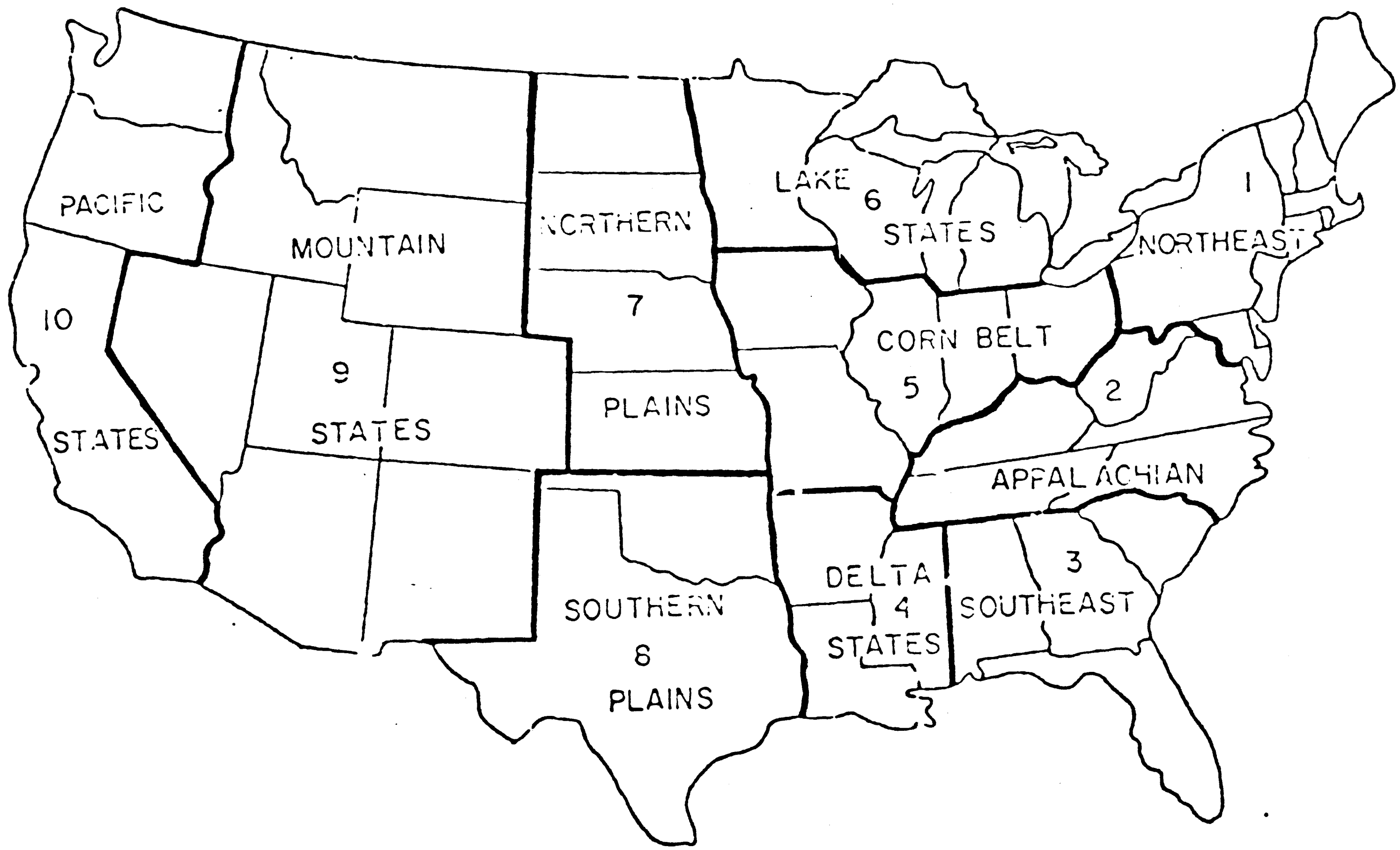


Figure 2. Location of consuming regions and livestock producing regions

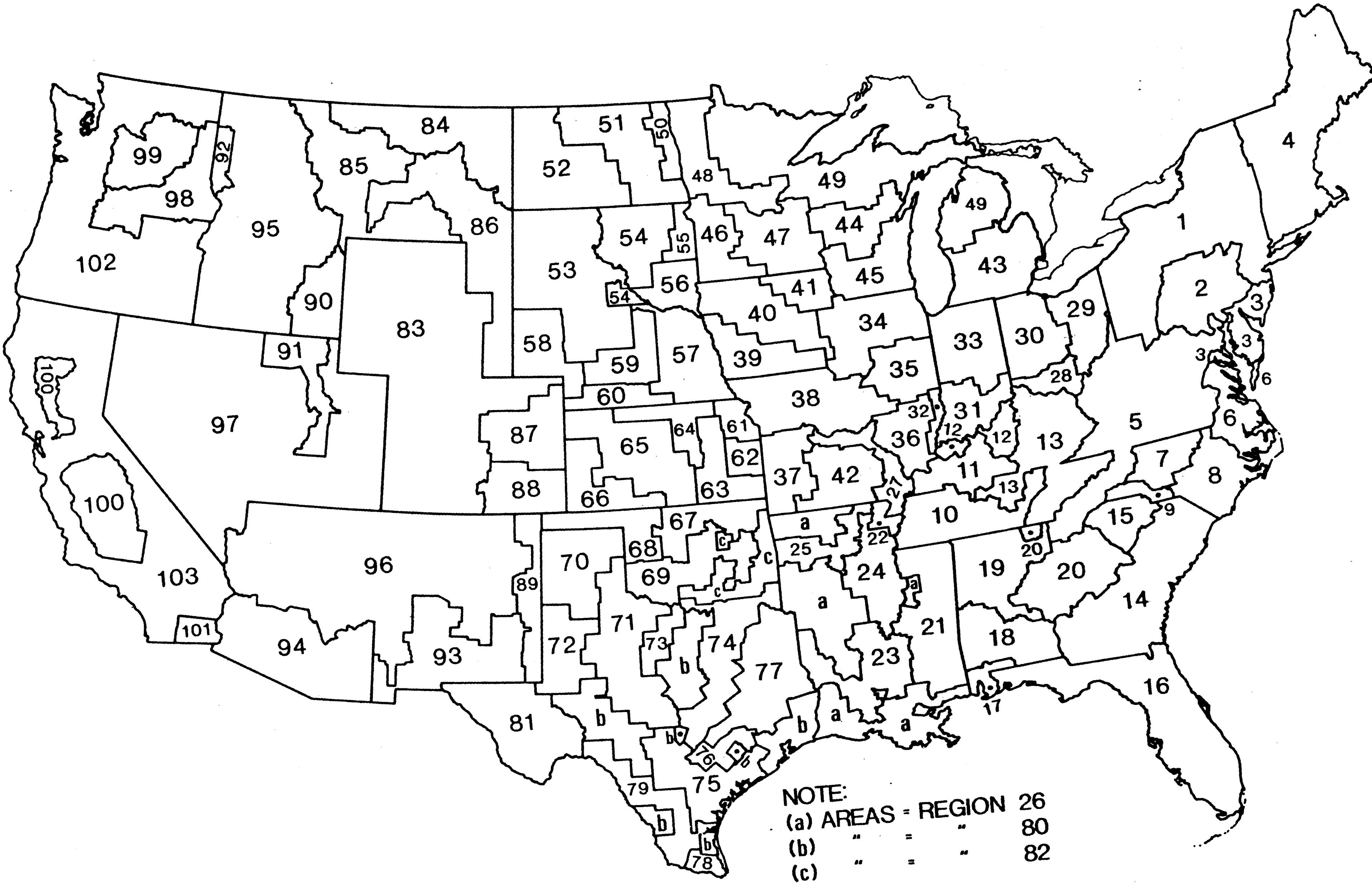


Figure 3. The 103 crop producing areas

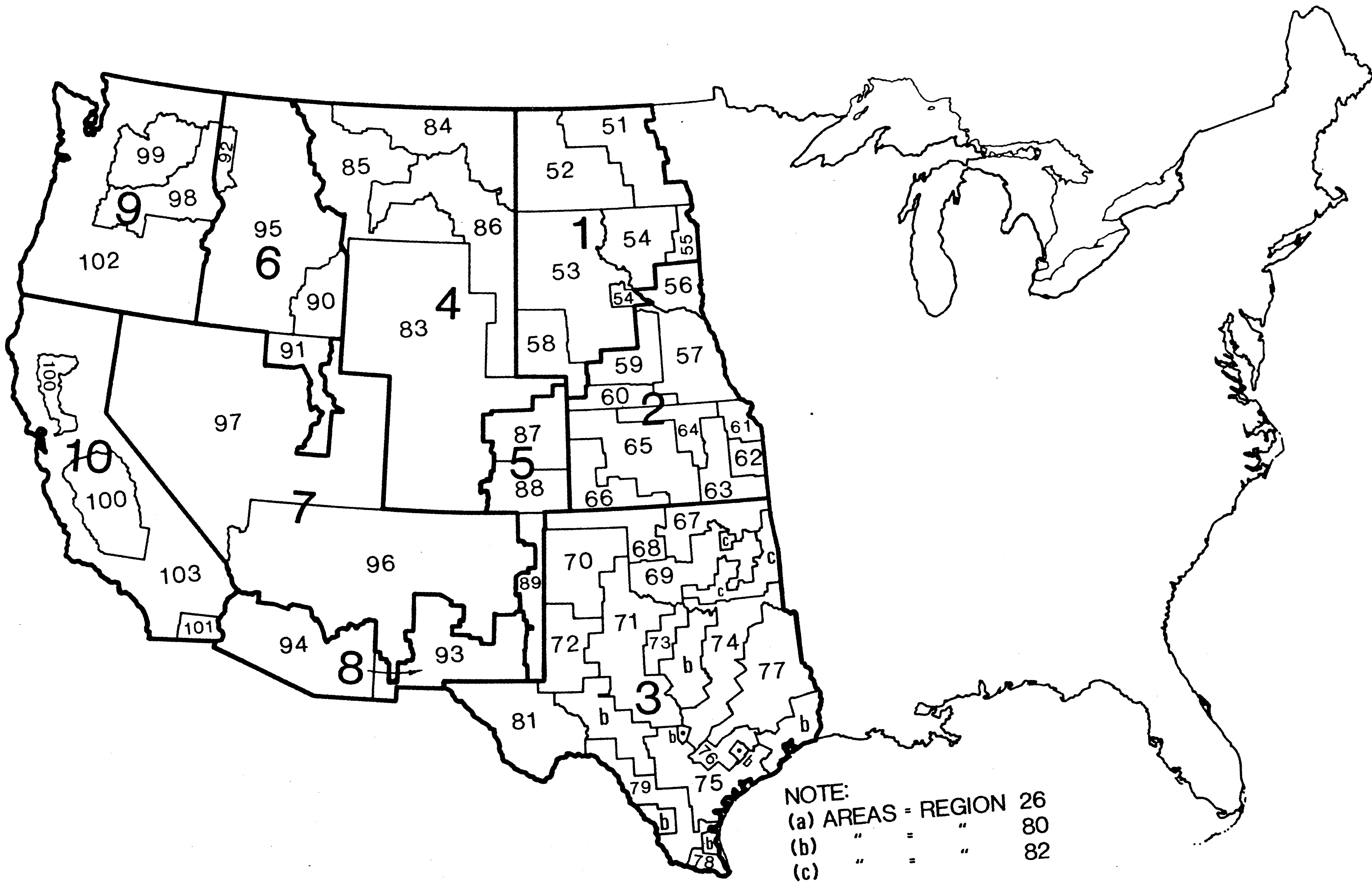


Figure 4. The 10 irrigated crop producing areas

and barley for food are perfect substitutes for corn, oats, and barley for feed, respectively, and vice versa. Wheat can also be used as a feed source. Demand can be satisfied by production within a region and(or) through commodities shipped from outside the region. Feed exogenous to the model can be purchased by the appropriate activity in the model. Inputs exogenous to the model are considered to be unlimited in quantity and at a given set price.

Table 1. Classification of commodities

Final or Desired	Intermediate	Primary
Cattle	Feed grains[a]	All cropland
Calves	Oilmeals[b]	All hayland
Hogs	Roughage	Irrigated cropland
Fluid milk	Feeder calves	Irrigated hayland
Manufactured milk[c]	Yearlings	Wild hayland
Wheat		Cotton land
Vegetable oils[d]		Pasture
Corn for food		Beef cow capacity
Oats for food		Milk cow capacity
Barley for food		Fed beef capacity
Sheep and lambs		Hog capacity
Chickens and turkeys		
Eggs		
Cotton lint		

[a]Feed grains include corn, oats, barley, and grain sorghum for feed.

[b]Soybean oilmeal and cottonseed oilmeal.

[c]Evaporated and condensed milk, cheese, ice cream, and butter.

[d]Soybean oil, cottonseed oil, and other food oils.

Definition of Activities

A crop activity is defined for a producing area if 1,000 acres or more of that crop was reported in the area in 1964. The set of possible crop activities is: (a) wheat, (b) corn, (c) oats, (d) barley, (e) feed grain (corn, oats, barley, grain sorghum), (f) feed grain-soybean rotation, (g) feed grain-hay rotation, (h) feed grain-silage rotation, and (i) hay-silage rotation. Irrigated crop activities are defined similarly. If cotton was grown in a consuming region in 1953, a cotton production activity is defined for that region.

A livestock activity is defined for a consuming region if 1,000 or more units of that activity were reported in that region on an annual basis between 1959-1968. The set of possible livestock activities is: (a) beef cow production, (b) fluid milk production, (c) manufactured milk production, (d) hog production, (e) yearling calf production, (f) Eastern deferred-fed cattle, (g) Southern deferred-fed cattle, (h) cattle on extended silage, (i) yearlings on silage, (j) calves on silage, and (k) yearlings with no silage. The following livestock activities are defined at the national level: hens and chickens, broilers and turkeys, and sheep and lambs.

The Mathematical Model

As discussed in Chapter II, the objective function for the national model (3.1) maximizes net aggregate producer profit. Net aggregate producer profit consists of revenue from sale of desired commodities plus value of intermediate commodities minus transportation costs. This objective function is maximized subject to the equilibrium conditions set forth in chapter II plus equilibrium conditions imposed on the transportation activities. The mathematical model is described below, but first let us define the terms. Subscripts and(or) superscripts are:

h = producing area = 1,2,...103

k = consuming region = 1,2,...,10

d = desired commodity = 1,2,...,14

i = intermediate commodity = 1,2,...5

s = substitutable commodity between intermediate and desired commodities = 1,2,3

j = primary commodity = 1,2,...,11

The terms are:

p^k, w^k, p_s^k, $u^{h \text{ or } k}$ = vectors of imputed prices for desired, intermediate, substitutable, and primary commodities, respectively, in region k or area h.

$x^{h \text{ or } k}$ = vector of production activities in area h for crop production and in region k for livestock production.

D = a matrix of demand slope coefficients with the vector of intercepts, d. This demand matrix is partitioned into submatrices for regional, regional-national, and national relationships.

z_1^k = transfer activity for food grains to feed grain markets.

z_2^k = transfer activity for feed grains to food grain markets.

z_3^k = transfer activity for converting feed grains into the units of TDN and protein by a conversion matrix, A_c, for livestock production.

e^k and e_s^k = vectors of exogenous demands for intermediate and substitutable commodities, respectively.

$r^{h \text{ or } k}$ = vector of primary resources in area h or region k.

$A_d^{h \text{ or } k}$, $A_i^{h \text{ or } k}$, $A_s^{h \text{ or } k}$, $A_j^{h \text{ or } k}$ = matrix of technical coefficients relating primary resources and other inputs into intermediate and desired commodities through production or transfer activities x and z in area h or region k.

$c^{h \text{ or } k}$ = vector of unit activity costs for intermediate and desired commodities in area h or region k.

$q_d^{kk'}$, $q_i^{kk'}$. $q_s^{kk'}$ = vectors of interregional shipment levels of desired intermediate, and substitutable commodities, respectively, from k to k' where $k \neq k'$.

t_d, t_i, t_s = vectors of transportation costs for those desired, intermediate, and substitutable commodities, respectively, for which transportation is defined.

$T_d^{kk'}$, $T_i^{kk'}$, $T_s^{kk'}$ = transportation matrices for the respective commodities.

To simplify reading, area and regional subscripts and superscripts are dropped; it is implied that the terms are expanded to have one set for each producing area or consuming region as is appropriate to the activity or imputed price vector. The objective function of the model is thus:

Maximize $f(p, w, p_s, u, x, z_1, z_2, z_3, q_d, q_i, q_s)$

$$= p(d + Dp) + w'e + p_s'e_s - u'r - x'c - q_d't_d - q_i't_i - q_s't_s \tag{3.1}$$

subject to:

$$\begin{array}{llllll}
Dp & -A_d x + z_1 - z_2 & & -T_d'q_d & \leq -d & (3.2) \\
 & -A_i x & -A_c z_3 & -T_i'q_i & \leq -e & (3.3) \\
 & -A_s x - z_1 + z_2 - z_3 & & -T_s'q_s & \leq -e_s & (3.4) \\
 & A_j'x & & & \leq r & (3.5) \\
A_d'p + A_i'w + A_s'p_s - A_j'u & & & & \leq c & (3.6) \\
-p \quad + p_s & & & & = 0 & (3.7)
\end{array}$$

$$A_c'w - p_s \leq 0 \qquad (3.8)$$

$$T_d p \leq t_d \qquad (3.9)$$

$$T_i w \leq t_w \qquad (3.10)$$

$$T_s p_s \leq t_s \qquad (3.11)$$

$$p,\ w,\ p_s,\ u,\ x,\ z_1,\ z_2,\ z_3,\ q_d,\ q_i,\ q_s \geq 0 \qquad (3.12)$$

Constraint (3.2) states that the supply of desired commodities must be greater than or equal to the demand for desired commodities. Constraints (3.3) and (3.4) state that the supply of intermediate and substitutable commodities must be greater than or equal to the demand for intermediate and substitutable commodities, respectively. Constraint (3.5) states that there is a limited supply of primary resources and no more than this maximum can be used in production.

Constraint (3.6) can be rewritten as:

$$A_d'p + A_i'w \qquad -A_j'u \leq c \qquad (3.6a)$$

$$A_s'p_s \quad -A_j'u \leq c_s \qquad (3.6b)$$

Here we see the requirement of marginal revenue being equal to or less than marginal cost plus rent of primary resources.

Equality constraints (3.7) are required because of the assumed perfect substitutability between corn, oats, and barley for food and feed. Constraint (3.8) cannot be used to equate internal prices ($A_c'w$) and final prices (p_s) because of problems of internal prices being zero if there is any excess supply. This problem is discussed in more depth by Chen (1975, p. 34-36). Constraints (3.9) through (3.11) are Samuelson's (1952) requirements for trade equilibrium stated in a slightly different form.

The Kuhn-Tucker conditions for optimality in quadratic programming, as discussed in chapter 2, are developed for this model. Taking these conditions and the affirmative test for the D matrix being negative semi-definite, the programming tableau that would be used in the computer is shown in Table 2. The skew symmetric properties needed in the constraint set for the self-dual problem are easily seen.

Before the model is solved and those results presented, the following sections will describe how the data was formulated. Stoecker (1974) gives a very detailed account of the estimation procedures. Unless otherwise specified, data noted as being 1959, 1964, or 1969 is taken from the U.S. Census of Agriculture for that year as published by the U.S. Bureau of the Census.

Demand Data

In 1961 Brandow published his set of direct price and cross-price elasticities for 28 major U.S. farm products. The demand for these commodities was described as a function of its own price, the prices of the other 27 commodities, consumer income, and the index of nonfood prices. These demand estimates encompassed changes in population growth, increases in consumer income, and changes in tastes. For this study, alternative forms of the Brandow system are analyzed. Demand equations for the following 13 commodities or commodity aggregates were used: cattle, calves, hogs, sheep and lambs, chickens and turkeys, eggs, fluid milk, manufactured milk, vegetable oils, wheat for food, corn for food and industrial use, oats for food and industrial use, and barley for food and industrial use.

Table 2. Structure of the present model in the programming tableau format

	Primal variables				Langrangian variables						
	Final commodity prices	Intermediate commodity prices	Substitutable commodity prices	Primary commodity prices	Production activities	Transfer activities			Transportation activities		
RHS	p	w	p_s	u	x	z_1	z_2	z_3	q_d	q_i	q_s
$-d_o \geq$	D				$-A_d$	I	$-I$		$-T_d$		
$-e \geq$					$-A_i$			$-A_c$		$-T_i$	
$-e_s \geq$					$-A_s$	$-I$	I	I			$-T_s$
$r \geq$					A_j						
$c \geq$	A'_d	A'_i	A'_s	$-A'_j$							
$0 \geq$	$-I$		I								
$0 \geq$	I		$-I$								
$0 \geq$		A'_c	$-I$								
$t_d \geq$	T'_d										
$t_i \geq$		T'_i									
$t_s \geq$			T'_s								

Revised time trends (shifts in the demand equation intercepts) affected by changes in taste were estimated while the other parameters of the Brandow system were retained. Reestimation equations used are given below where (3.14) is derived from (3.13) and then the time trend equation for the demand intercept is given.

$$q_{it} = d_{it} + D_i P_t \tag{3.13}$$

$$d_{it} = q_{it} - D_i p_t = a_o + a_1 T + e_t \tag{3.14}$$

where q_{it} = total quantity of the ith commodity demanded in year t,

d_{it} = demand intercept of commodity i in year t,

D_i = the ith row of the demand matrix, D,

P_t = set of prices, consumer income, and the index of nonfood prices in year t.

Ordinary least squares is the estimation procedure used. If the Durbin-Watson statistic showed that autocorrelation was present, a one-step autocorrelated error model was used.

For the demand matrix itself, Stoecker (1974, p. 34-38) describes the method of selecting the variation of Brandow's system. Briefly, three algebraic forms of the demand equations were viewed: 1) constant elasticities, 2) Brandow's slopes, and 3) Hall's (1969) slopes. Alternatives in two other areas were also looked into: (a) nominal vs. deflated[1] farm level

[1]Deflated by the index of prices received by farmers. See Learn (1956).

prices and (b) constant total farm level demand slopes vs. constant per capita demand slopes.

Comparisons between results from the variations were based on the Theil's U statistic, the standard error of the equation, the average relative error, and the absence of first order autocorrelation. The per capita form of the demand equation was selected because of its greater consistency with the idea of the representative consumer and its performance was slightly better than the total market demand forms. Nominal prices generally performed better than deflated prices.

The constant elasticity forms of the Brandow equations were the better of the three alternatives. However, linear demand equations are needed in the constraint set so these were based on converting Brandow's elasticities to slopes using 1963-65 average prices and quantities. The national demand matrix and intercepts, corrected for exports, are given in Table 3.

This national demand matrix is partitioned on the basis of population into regional demand matrices for 10 commodities. Demand for other desired commodities is defined as follows: cotton lint demand is fixed at a national level; demand equations for chickens and turkeys, eggs, and sheep and lambs are specified on the national level.

The regional demand matrix is partitioned into the submatrices below:

$$B_k' = \left(\begin{array}{c|c} D_{rk} & C_k \\ \hline R_k & D_{nk} \end{array}\right) \tag{3.15}$$

Table 3. National, farm-level demand for food use in 1980; slope coefficients showing the effect of a one-unit change in the farm price of the commodity at the head of a column on the demand for the commodities in the row and domestic intercept terms[a]

Commodity[b]	Cattle	Calves	Hogs	Fluid milk	Mfg. milk	Oil	Wheat	Corn	Oats	Barley	Sheep & lambs	Chickens & turkeys	Eggs	Intercept
CA	-1,300.260	67.598	124.640	0.048	3.983	0.125	2.657	1.066	0.167	0.024	60.329	2.965	149.687	72,822.8
CF	26.636	-97.912	11.853	.002	.205	.007	.137	.055	.009	.001	5.569	.153	14.096	1,438.4
HG	109.692	26.200	-559.373	.029	2.388	.075	1.593	.639	.100	.041	31.532	1.778	79.231	25,268.4
FM	2.092	.322	1.069	-20.902	1.678	.017	.085	.034	.005	.001	.194	.269	.909	5,209.1
MM	4.787	.739	2.448	1.611	-84.624	4.503	.458	.184	.028	.004	.446	.560	2.081	8,671.2
ØL	.437	.068	.224	.030	3.544	-1.845	.034	.014	.002	.001	.041	.042	.190	2,286.4
WH	6.619	1.023	3.387	.450	1.233	.046	-9.892	.730	.114	.016	.618	.865	2.878	14,703.0
CN	4.336	.670	2.219	.295	.809	.030	1.194	-13.940	.075	.011	.405	.566	1.886	4,757.5
ØT	.597	.092	.305	.041	.111	.004	.164	.066	-2.563	.002	.056	.078	.260	590.5
BY	.067	.010	.035	.005	.013	.001	.019	.007	.001	-9.297	.006	.009	.029	1,401.1
SL	43.197	10.319	26.258	.002	.203	.006	.135	.054	.009	.001	-181.712	.151	21.736	3,123.1
CT	3.732	.577	1.910	.254	.578	.016	.294	.118	.019	.003	.349	-40.394	1.623	6,733.5
EG	74.863	17.881	45.512	.013	1.056	.033	.703	.282	.044	.006	15.156	.785	-466.177	17,650.7

[a]Commodity units are as follows: cattle, calves, hogs, fluid milk, manufactured milk, oil, sheep and lambs and poultry meat in cwt.; wheat, corn, oats and barley in bu.; eggs in hundred dozen. All prices in 1963-65 dollars per quantity unit are given above. Quantity changes are in 10,000 units.

[b]Commodity code: CA, cattle; CF, calves, HG, hogs; F, fluid milk; MM, manufactured milk; ØL, oil; WH, wheat; CN, corn, ØT, oats; BY, barley; SL, sheep and lambs; CT, chicken and turkey; EG, eggs.

where

B'_k = 13 x 13 matrix of demand slopes for consuming region k, k = 1,2,...,10,

D_{rk} = 10 x 10 matrix measuring the effect on regional demand in terms of regional prices,

C_k = 10 x 3 matrix relating the effect of national prices to quantities demanded in region k,

R_k = 3 x 10 matrix relating the effect of prices in region k to national demands, and

D_{nk} = 3 x 3 subregion demand matrix. Summation of D_{nk} over k equals D_n.

C_k, R_k, and D_{nk} are necessary due to the specification of demand of three commodities on the national level and not on the regional level.

The regional demand matrices, B'_k, are derived from the national demand matrix by the following relationship:

$$B'_k = w_k * D \tag{3.16}$$

where

w_k = proportion of total population in the kth region (Table 4),

D = national demand matrix (Table 3).

The regional demand intercepts are derived in a manner similar to the regional slopes, but the intercepts are also adjusted for expected regional differences in personal disposable income:

$$d_k = w_k \left[d + I_d(I_k - I_{us})\right] \tag{3.17}$$

where new terms are defined as

d_k = regional demand intercept,

d = national demand intercept,

I_d = regional factor relating changes in personal disposable income to the quantity demanded at the national level,

I_k = expected personal disposable income per capita for the kth consuming region (Table 4),

I_{us} = expected personal disposable income per capita for 48 states and District of Columbia (Table 4).

The schemata specified below shows how the regional demand matrices are fitted together to yield regional and national price relationships.

Region	RHS	Regional Prices					Nat'l Prices
NE	d_1	D_{r1}					C_1
AP	d_2		D_{r2}				C_2
SE	d_3			D_{r3}			C_3
.	.				.		.
.	.				.		.
.	.				.		.
DC	d'_{10}					D_{r10}	C_{10}
US	$d_{Nat'l}$	R_1	R_2	R_3	. . .	R_{10}	D_n

Since the national demand matrix tests affirmative for negative semi-definiteness, it can be readily shown that the form of the matrix in the schemata is still negative semi-definite. Thus, the convexity properties of the constraint set are not impaired and so the optimality conditions remain intact.

Domestic demand for cotton lint is set at 17 pounds per capita, or 8.1 million bales. Net commercial export of cotton is set at the 1964 level, 4.2 million bales. Total demand for cotton lint is thus 12.3 million bales.

Table 4. Projected population and personal disposable income[a] by consuming regions for 1980[b]

Consuming region	Population	Population proportions	Personal disposable income
	(millions)		(per capita)
Northeast	61.016	0.266	3602.2
Appalachia	20.246	0.088	2723.2
Southeast	20.198	0.088	2691.2
Delta	8.095	0.035	2457.6
Corn Belt	38.552	0.168	3406.4
Lake States	19.419	0.085	3428.8
N. Plains	5.206	0.023	2919.2
S. Plains	15.445	0.067	2864.8
Mountain	9.620	0.042	2896.8
Pacific	31.169	0.136	3642.4
United States[c]	228.964	1.000	3260.0

[a]Measured in 1963-1965 dollars.

[b]Source: (U.S. Department of Commerce, 1968).

[c]48 states plus District of Columbia.

Demand for a desired commodity is allowed to be satisfied by production in any region using the available transportation activities. Production within a consuming region satisfies that region's demand with no transportation costs.

Exports

In this model, exports are defined as net exports (i.e., total commercial exports less imports). Estimates of net exports were made for all of the desired commodities plus feed grains and oilmeal. These estimates of 1980 foreign demand are either a fixed amount or based on a linear equation involving an intercept and an inverse relation to the commodity's own price. In estimating the export levels, a simple time trend estimation was used to give "normal" exports. These normal exports are lower than the export levels of the past few years. For wheat, the estimated export demand for 1980 is 1,000 million bushels compared to a 1968-1970 average of 628 and a 1972-1973 average of 1,165 million bushels. Corn exports for 1980 are set at 950 million bushels; this compares to 553 and 1,250 million bushels for 1968-1970 and 1972-1973 average exports, respectively.

Allocation of net exports among ports and thus consuming regions is made from historical patterns of shipment. These regional equations or intercepts are added to the appropriate rows in the demand matrix. The national matrix for both domestic and export demand is in Table 3.

Exogenous Feed Demands and Supplies

The model includes only the major livestock production activities and thus leaves out a portion of feed demand. Brokken (1965) estimated the feed and pasture needs of these exogenous animals and they have been treated as fixed negative supplies in the appropriate rows of the demand intercept vector.

The crop activities described in the following sections do not produce all the feed supplied to the livestock industry. Fishmeal, linseed meal, rice mill-feeds, corn gluten meal, wheat bran and middlings, and brewers' by-products, for example, are available from various non-agricultural sources and thus exogenous to this model. Brokken (1965) grouped these feeds into four categories: F_1; oilmeals other than soybean and cottonseed oilmeals, F_2; animal protein feeds, F_3; grain proteins, and F_4; other. Estimated national supplies and assumed nutrient contents of these feeds are given in Table 5.

Transfer activities permit the movement of exogenous feeds from national to regional supplies, where they can be used by the livestock activities. Assumed transfer costs are given in Table 6.

Land Base and Rotation Weights

Land resources in the continental United States are defined as cropland, cropland plus hayland, irrigated cropland, irrigated cropland plus hayland, wild hayland, pasture, and cotton land. Cropland is defined as the total 1964 acreages of wheat, all corn, oats, barley, soybeans, sorghum (grain, silage, and forage) and cotton plus estimates of cropland idled by the wheat, feed grain and cotton programs. Cropland plus hayland is defined as cropland (as defined above) plus the 1964 acreages of alfalfa, clover, timothy, lespedeza, grain hay, and other hay. These first two land resources are defined on the producing area level.

Irrigated cropland and irrigated cropland plus hay lands are defined similarly to nonirrigated land except the acreages are adjusted to include land brought under irrigation through 1969 and estimates of new irrigated land from Bureau of Reclamation projects scheduled for completion by 1980 (Heady, Madsen, Nicol, and Hargrove, 1972). Irrigated land use is distributed to the producing areas within each irrigated

Table 5. Estimated national supplies and assumed nutrient contents of exogenous feeds

Exogenous feed	Quantity[a] (1000 tons)	TND[b] (percent)	Protein[b] (percent)
F_1	498	76.9	36.9
F_2	2,676	70.5	55.0
F_3	1,898	77.0	28.0
F_4	11,568	69.1	18.0

[a]Source: (Brokken, 1965; p. 180).

[b]Source: (Eyvindson, 1970).

Table 6. Transfer costs for moving exogenous feeds to regional feed supplies, dollars per 100 pounds[a]

Livestock region[b]	Exogenous feed			
	F_1	F_2	F_3	F_4
NE	4.82	5.12	3.47	3.20
AP	5.05	5.33	3.41	3.19
SE	5.28	5.20	3.48	3.39
DL	5.50	5.50	3.03	2.82
CB	4.72	5.53	3.12	2.98
LK	4.24	5.72	3.16	2.78
NP	4.59	5.50	3.03	2.71
SP	5.20	5.50	3.03	2.60
MT	5.23	5.50	3.03	2.82
PC	5.53	5.50	3.03	3.39

[a]Source: (Brokken, 1965; p. 579). Brokken's cost are in dollars per hundredweight of feed units (A). Multiply by feed units per unit of feed (B) to get dollars per hundredweight of feed (C): A x B = C. B values: F_1, 1.65; F_2, 1.00; F_3, 1.45; F_4, 1.25.

[b]Regional code: NE, Northeast; AP, Appalachia; SE, Southeast, DL, Delta; CB, Corn Belt; LK, Lake States; NP, Nothern Plains; SP, Southern Plains; MT, Mountain States; PC, Pacific States.

region by a fixed proportion. Let p_i^c be the proportion of irrigated cropland in the ith producing area within a region. Within a region the sum of p_i^c over all areas is set equal to one. Let p_i^{ch} be the proportion of irrigated cropland plus hay land in the ith producing area within a region. Within a region the sum of p_i^{ch} over all areas is set equal to one. The irrigated crop activities are designed so to remove land from the regional total land resource and also p_i^c proportion of cropland and cropland plus hay land or p_i^{ch} proportion of cropland plus hay land in each area in that region.

Wild hay land is the 1953 harvested acreage of wild hay. The year 1953 is used because it is the last in which acreages were not significantly affected by government programs.

Pasture is measured in animal unit months (AUM) available for livestock production in each of the 10 livestock producing regions. Pasture includes woodland pasture, permanent pasture, improved permanent pasture, cropland pasture, unimproved permanent pasture, and aftermath pasture. In addition, all land resources, except wild hayland, are assumed to produce pasture if not used for crop production. Thus each consuming region has a total AUM figure which is decreased as crop production takes place in that region.

Cotton land is the 1953 acreage in each consuming region. Again, the year 1953 is used because of nonsignificant influence of government programs. This regional acreage is distributed among the producing areas within that region by a fixed proportion based on the 1964 distribution of cotton acres similar to that system used for the irrigated land using cp_i^c as the proportion in area i.

In Table 7 the relationships between the land resources are illustrated by showing various activities in producing area i, consuming region j, and irrigated region k where i = 1,2,...,103 (Figure 3); j = 1,2,...,10 (Figure 2); and k = 1,2,...,10 (Figure 4).

Table 7. The general relationships between the land resource categories [a]

	Activities				
Land Resource	Grain in area i	Hay in area i	Irrigated grain in region k	Irrigated hay in region k	Cotton in region j
Total Pasture Supply$_j$	AUM[b]	AUM	AUM	AUM	
Cropland$_i$	1		p_i^c	p_i^{ch}	cp_i^c
Cropland plus Hayland$_i$	1	1	p_i^c	p_i^{ch}	cp_i^c
Irrigated Cropland$_k$			1		
Irrigated Cropland plus hayland$_k$			1	1	
Cotton land$_j$					1
Grain Supply Row	-gy[c]		-gy		
Roughage Supply Row		-hy		-hy	
Cotton Supply Row					-cy

[a]The subscripts i, j, and k are appropriately matched when needed.

[b]This AUM is the amount of available pasture lost when a crop producing activity uses the said amount of land.

[c]These yields (gy, hy, and cy) are symbolic and will change with region and type of production.

With each crop defined singly as an activity, the programming model has a tendency to produce only one crop in each area. To overcome this tendency, activities are defined to give joint products of these crops. Feed grains is an example of where these activities are developed. The relative proportions (rotation weights) of each of these individual crops in the feed grain activity was based on the total acreage of each crop in 1964 and 1959 in each producing area. These historical weights are defined for the following rotational activities: feed grains, feed grain-soybean, feed grain-silage, feed grain-hay, and hay-silage. Stoecker (1974) and Chen (1975) have these weights specified in their appendices.

Cost Projection

For crop activities, exogenous costs are categorized and estimated as: (1) labor, (2) fertilizer, and (3) other capital costs. Exogenous costs for livestock activities are (1) labor and (2) other capital costs.

Labor costs are projected to 1980 by using an index developed by relating relative labor requirements for each commodity to changes in farm size and lagged relative capital requirements. Stoecker (1974) developed this index to project 1964 requirements to 1980 by the 10 consuming regions and commodities within the model (Table 8).

Using 1963-1965 prices, fertilizer costs are estimated from the optimal fertilizer applications for each crop in each production area (estimated in the following section on crop yield projections).

Table 8. Estimated requirements for nonfertilizer capital and labor per activity unit in 1980 relevant to 1964[a] by consuming region for commodities included in the programming model

Region[b]	Wheat		Feed Grain		Cotton		Soybeans		Meat animal		Dairy		Roughage	
	Cap.	Labor	Cap.	Labor	Cap.	Labor	Cap.	Labor	Cap.	Labor	Cap.	Labor	Cap.	Labor
NE	1.53	.74	1.40	.74	--	--	1.28	.67	1.26	.69	1.39	.71	1.48	.92
AP	1.74	.79	1.51	.68	1.52	.54	1.52	.53	1.99	.59	1.57	.83	1.54	.87
SE	1.88	.91	1.45	.81	1.76	.49	1.47	.44	1.64	.70	1.66	.79	2.00	.92
DL	1.23	.81	1.41	.68	1.79	.38	1.38	.79	1.40	.78	1.69	.92	1.37	.93
CB	1.33	.86	1.28	.81	1.48	.48	1.30	.94	1.42	.65	1.29	.66	1.24	.98
LK	1.29	.84	1.24	.84	--	--	1.16	.72	2.06	.64	1.26	.64	1.26	.93
NP	1.61	.88	1.24	.91	--	--	1.28	.63	1.22	.58	1.21	.72	1.26	.96
SP	1.44	.75	1.39	.91	1.58	.65	1.16	.29	1.65	.72	2.01	.81	1.67	.91
MT	1.28	.89	1.24	.95	1.20	.39	--	--	1.15	.68	1.67	.77	1.57	.96
PC	1.26	.84	1.16	.95	1.17	.47	--	--	1.49	.96	1.15	.51	1.27	.97

[a]To estimate for 1980, the 1964 requirements are multiplied by the appropriate coefficient (e.g., wheat in the Northeast region requires 1.53 times the capital in 1980 as required in 1964, but it requires only 0.74 times the labor in 1980 as in 1964).

[b]Region codes given in Table 6.

Other capital costs included all other exogenous costs besides fertilizer and labor. Eyvindson (1970) developed cross-section estimates of exogenous costs required per activity unit for the year 1965. Using these estimates Stoecker (1974) developed a set of time series cost equations for cost projection to 1980. The main source of data used, other than Eyvindson, is the expenditure data for farmers by states by year from 1949 to 1969 (United States Department of Agriculture-Economic Research Service, 1964 and 1971b).

Within each state there are 12 categories of production defined: (a) meat animals, (b) dairy products, (c) poultry, (d) other livestock, (e) wheat, (f) feed grains, (g) cotton, (h) tobacco, (i) soybeans, (j) vegetables, (k) harvested roughages, and (l) fruits, nuts, greenhouse, nursery, and all other crops. The total expenditure by farmers (except for labor and fertilizer) is allocated among the 12 categories by one of three methods: (1) value-weighted, (2) value of production, or (3) direct allocation (Table 9).

Based on this set of derived cost data, an index of capital inputs per activity for each commodity output category is developed. These indices are used to project other capital costs for 1964 are estimated from a regression function of farm size, lagged capital inputs, capital/labor ratios, and factor/product price ratios.

Crop Yield Projections

Crop yields for 1980 are projected on the basis of historical trends adjusted for change in the proportion of acreage under irrigation and for changes in fertilization practices. Fertilization practices analyzed were the proportion of the crop acreage receiving fertilizer and the quantity of fertilizer applied per acre fertilized.

Table 9. Inputs considered exogenous[a] and their method of allocation between production categories

Method	Inputs
Value-weighted	Depreciation, interest, repairs, and insurance and license fees
	Tractors
	Trucks
	Other farm machinery
	Service buildings
	Pesticides
	Veterinary expense
	Crop-hail insurance
	Federal crop insurance
	Electricity
	Irrigation
	Telephone
	Seed purchases
Value of production	Miscellaneous hardware
	Small hand tools
	Accidental damage
	Marketing charges[b]
Direct allocation	Ginning expense to cotton production
	Dairy supplies, hired milk hauling to dairy production
	Greenhouse and nursery, syrup tolls to nursery, greenhouse, and all other crops
	Containers to vegetables

[a]These inputs are exogenous in the sense that their values were considered predetermined.

[b]Marketing charges were distributed between meat animals and dairy production according to estimated quantity of meat sold for slaughter.

For each state and crop, response to fertilization was assumed to be given by a single variable Spillman function:

$$Y_t = Y_t^o + A(1 - R^{x_t})\ P_t \tag{3.18}$$

where

Y_t = estimated average per acre yield in year t;

Y_t^o = estimated average per acre yield on unfertilized land in year t plus other effects described shortly;

A = potential response obtainable from fertilization and is assumed constant;

R = 0.8 for all crops;

x_t = optimal quantity of fertilizer applied to an acre of land in year t;

P_t = proportion of acreage receiving fertilizer in year t; and

t = years after 1949.

In the normal Spillman formulation, R is the ratio of successive marginal products. Ibach and Adams (1968) suggest holding R constant (at 0.8) for all crops and redefining the unit of fertilizer. This redefinition consists of dividing the total poundage of elemental nitrogen, phosphorus, and potassium by a factor which Ibach and Adams obtain by regression.

Since A and R are held constant, the term $A(1-R^{x_t})$ represents the response from fertilization only. The response to factors other than fertilization must then be in the term Y_t^o where Y_t^o can be defined in terms of (3.18) or as a simple linear time regression:

$$Y_t^o = Y_t - A(1 - R^{x_t})P_t = a_0 + a_1\ T + e_t \tag{3.19}$$

where all terms are as described previously and T is a time variable with T for 1964 = 0. Thus we see that Y_t^o is the average per acre yield on unfertilized land plus the yield increases due to technical changes over time other than fertilization rate changes.

The profit maximizing application rate of fertilizer is given in equation (3.20):

$$x_t^* = \frac{\ln\left(\frac{P_{x,t-1}}{P_{c,t-1}}\right) - \ln A - [\ln(-\ln R)]}{\ln R} \tag{3.20}$$

where

x_t^* = optimal number of units of fertilizer to be applied,

ln = natural logarithm operator,

$P_{c,t-1}$ = price of a unit of crop c, lagged one year,

$P_{x,t-1}$ = weighted price of one unit of fertilizer (as redefined), lagged one year,

R = 0.8, and

A = potential response from equation (3.18).

Because changes in the factor/product price ratio do not account for all of the increased applications of fertilizer, these increases were viewed as an adjustment to the optimal level. Projected fertilizer application rate ratios are based on equation (3.21).

$$\frac{x_t^a}{x_t^*} = q_o + q_1 T + w_t, \quad q_1 \geq 0 \tag{3.21}$$

where

x_t^a = estimated actual rate of application in year t.

The projected proportion of acreage receiving fertilizer is based on a linear time analysis:

$$P_t = f_o + f_1 T + u_t \qquad (3.22)$$

Crop yield projections at the state level for 1980 (3.23) under specificed prices are made by evaluating equations (3.19) through (3.22) for t = 16 (i.e., 1980-1964 = 16):

$$Y_{80}^0 = a_0 + 16a_1 \qquad (3.19a)$$

$$X_{80} = X_{80}^* \text{ (minimum } [1.0,\ q_0 + 16q_1]) \qquad (3.20a \ \& \ 3.21a)$$

$$P_{80} = \text{minimum } [1.0,\ f_0 + 16f_1] \qquad (3.22a)$$

$$Y_{80} = Y_{80}^0 + A\ (1 - R^{x_{80}})P_{80} \qquad (3.23)$$

Stoecker (1974) describes the changes in the above procedure which were made to evaluate the irrigated and nonirrigated yields in the 17 Western states.

A Spillman production function is now specified for each crop activity defined in the 103 producing areas and the 10 irrigated producing areas. This is done by aggregating equation (3.20) over the Ibach and Adams' (1968) subregions which intersect with the area and by aggregating equations (3.19), (3.21), and (3.22) over the states which intersect with the area.

Livestock Activities

Livestock production activities for beef cows, hogs, dairy, and beef feeding are defined for each of the 10 consuming regions. A specific list of the 11 activities is given above. National production activities are defined for hens and chickens; broilers and turkeys; and sheep and lambs.

The nationally defined production activities do restrict some movement, but there is still more flexibility available than if they were exogenous to the model (i.e., the national level of production is determined endogenous to the model with respect to the other prices and quantities). Each national activity withdraws feed (TDN, protein, and roughage) from each consuming region in accordance with the 1963-65 distributions of that activity.

These livestock activities are limited in size similar to the land restraints on crop production. The hog capacity and milk cow capacity for a region are defined as the maximum, historical number of hogs and milk cows in annual inventory in that region between 1959-68. The regional capacity constraints for beef cows and for fed beef are based on historical trends in annual inventory numbers for each region between 1959-68.

The actual feed required per unit of production for each live animal is adjusted from the 1963-65 levels as given in the USDA series on Livestock and Meat Statistics and other government sources except for dairy and for broilers and turkeys. Feed requirements and milk production per dairy cow are estimated recursively to provide consistent projects of relations between feed input and milk output. Data from 1949 to 1969 is used in the following recursive system in each state:

$$F_t = a_0 + a_1 T + e_t \tag{3.24}$$

$$M_t = b_0 + b_1 F'_t + u_t \tag{3.25}$$

where

F_t = total feed intake measured in total digestable nutrients in year t,

M_t = milk per cow in year t, and

F'_t = predicted TDN required per cow in year t.

The individual state projections are aggregated into consuming region level projections using 1963-65 dairy cow numbers as weights.

Projected feed required for broiler and turkey production is obtained from linear trends using an autoregressive least squares technique as described in Fuller and Martin (1961).

Transportation Activities

A transportation system is available from outside the sector and the (a) cattle, (b) hogs, (c) manufactured milk, (d) oils, (e) wheat, (f) corn, (g) oats, (h) barley, (i) feed grains, (j) oilmeals, (k) feeder calves, and (1) yearling cattle. The central cities in each region used for estimating transportation costs are listed in Table 10. Certain transportation activities have not been included because of little chance of occurrence in the actual transportation network (e.g., shipping wheat from Iowa to Kansas). Also, to economize, any transportation activity that did not occur in any of Brokken's (1965) 26 solutions were dropped from the possible activities in this model.

Table 10. Central cities in the consuming regions for transportation purposes

Region[a]	Central City
NE	Boston, MA
AP	Richmond, VA
SE	Atlanta, GA
DL	Jackson, MS
CB	Burlington, IA
LK	Minneapolis, MN
NP	Grand Island, NE
SP	Waco, TX
MT	Salt Lake City, UT
PC	San Francisco, CA

[a]Region codes are given in Table 6.

Transportation costs are functions of distance and the mileage rate. Distances between the central cities are based on rail mileage estimated by Eyvindson (1970). Except for oils, mileage rates are rail mileage block rates also based on Eyvindson. Thompson (1967) provided the basis for the mileage rates for oils. The transportation activities defined and the associated costs are based on Hall (1969, p. 196-204).

Predictions for 1980

This study examines the effects of two environmental government policies and their impacts upon U.S. agriculture in 1980. To assess these impacts, a point of reference is needed. The model described in the previous sections of this chapter will be the point of reference for this study.

The model reflects U.S. agriculture in 1980 without governmental controls on agricultural practices, methods, or habits. It does not include price supports, export controls, and set-aside programs. This solution is hereafter referred to as Solution I and the model as Model I. Estimates for 1980 in Solution I are presented in Tables 11 through 20 with only brief comments.

Estimates of prices and consumption for 1980, Solution I, compare favorably with 1963-65 and 1968-70 average levels (Table 11). On-the-farm commodities do not mean, with cattle as an example, that people consume 196 pounds of steaks, ribs, hamburgers, etc., but on-the-farm commodities do mean a person's consumption of beef is equivalent to 196 pounds of liveweight, on-the-hoof beef. Estimated national prices for intermediate commodities are presented in Table 12.

In interpreting the levels of the prices, several points should be kept in mind. These prices do not incorporate fixed costs, but they still serve as a basis for comparison in price levels of other models. In other words, if fixed costs were included, the equilibrium prices generated in all of the models would be higher. However, since fixed costs are not included in any of the model solutions, they are comparable in level of prices. Thus, since they are affected relatively the same, comparison of price results between the different solutions appear relevant. A set of normal export demands was used in projections to 1980. As indicated in Table 13, these export levels are lower than those experienced in the period 1973-75. Hence, at the export levels, U.S.

Table 11. Estimated national equilibrium prices, total domestic consumption and per capita consumption for selected, on-the-farm commodities. Solution I compared with average values for 1963-65 and 1968-70.

Commodity	1980 Solution I			Actual 1963-65[c]			Actual 1968-70[c]		
	Price[b]	Domestic Consumption	Per Capita Consumption	Price	Domestic Consumption	Per Capita Consumption	Price	Domestic Consumption	Per Capita Consumption
	($/lb.)	(mil. lb.)	(lb.)	($/lb.)	(mil. lb)	(lb.)	($/lb.)	(mil. lb)	(lb.)
Cattle	0.27	44,901	196.1	0.19	33,872	178.9	0.31	37,651	188.9
Calves	.19	186	0.8	.22	-	-	.26	-	-
Hogs	.15	22,120	96.6	.17	19,744	104.3	.21	21,147	106.1
F. milk	.02	48,393	211.4	.04	59,222	313.0	.06	55,462	278.9
M. milk	.02	82,075	358.5	.04	62,991	333.0	.05	59,150	296.0
Oils	.02	8,922	39.0	.11	5,714	30.2	.11	7,136	35.8
Sheep & Lambs	.22	1,194	5.2	.18	1,317	7.0	.23	1,083	5.5
Eggs[a]	.21	6,091	26.6	.34	5,068	26.4	.37	5,394	26.5
Poultry	.09	16,999	74.2	.16	8,170	41.0	-	-	-
Cotton	.02	3,892	17.0	.15	10,597	22.8	.15	13,246	20.9
	($/bu.)	(mil. bu.)	(bu.)	($/bu.)	(mil. bu.)	(bu.)	($/bu.)	(mil. bu.)	(bu.)
Wheat	1.30	486	2.1	1.52	509	2.7	1.27	520	2.6
Corn	.86	488	2.1	1.15	338	1.8	1.19	378	1.9
Oats	.46	61	0.3	0.62	45	0.2	0.60	45	0.2
Barley	.76	133	0.6	0.95	102	0.5	0.91	120	0.6

[a]Unit on eggs is dozen to give the appropriate column headings: $/doz., mil. doz., and doz.

[b]Weighted average of regional prices with production as weights. Measured in 1963-65 dollars.

[c]Source: (U.S. Department of Agriculture, 1973; U.S. Department of Agriculture-Economic Research Service, 1971a).

Table 12. Estimated national prices[a] received by farmers for intermediate commodities for 1980, Solution I

Commodity	Estimated 1980 price
	($/bu.)
Corn	0.86
Oats	0.46
Barley	0.76
Grain sorghum	0.88
Soybeans	3.00
	($/ton)
Oilmeal[d]	141.25
Roughages	20.80
	($/head)
Feeder calves[b]	147.10
Yearlings[c]	193.81

[a]1963-65 real dollars.

[b]400 pounds per head.

[c]700 pounds per head.

[d]Dollars per hundredweight.

Table 13. Estimated net international commercial exports[a] for selected commodities on national level for Solution I with comparisons of average 1968-70 and 1972-73 figures

Commodity	Unit	1980 Sol. I	1968-70 Actual[b]	1972-73 Actual[b]
		(million units)		
Cattle	lb.	-2,377	-1,563	-1,871
Pork	lb.	-230	-188	-266
Wheat	bu.	1,000	628	1,165
Corn	bu.	950	553	1,250
Soybeans	bu.	863[c]	385	509

[a]Negative terms denote net imports.

[b]Souces: Cattle and pork (U.S. Department of Agriculture-Economic Research Service-Statistical Reporting Service-Agricultural Marketing Service, 1975); wheat, corn, and soybeans (U.S. Department of Agriculture, 1975).

[c]Estimate of soybean and cottonseed meal net exports in soybean equivalent bushels.

agriculture still has "excess supply capacity," as it did up through 1972. In contrast to the 1970-72 period, however, the model does not include supply control, price support, and international food aid programs such as those in effect prior to 1973. The prices reported here and in later sections are under conditions of a free market and "normal" exports. They also are of a short-run nature (expressing conditions before farmers would shift resource use in response to price levels) and in terms of 1963-65 dollars and thus do not include the effects of inflation of the past few years.

Net commercial exports are reported in Table 13. Cattle and pork net exports are determined by an intercept and slope on price while wheat, corn, oil, and oilmeal exports are determined by an intercept based on the export trend extended to 1980. Thus, net exports for cattle and pork will change between solutions but the other exports are assumed constant. Interregional shipments of commodities are allowed to change between models. The shipments occurring in Solution I are specified in Table 14.

In Solution I, 21.5 percent of nationally available cropland is not needed for crops (Table 15) after all demands have been met at the export levels indicated. Nationally, 24 percent of available cropland plus hayland is not needed for these uses. No region is completely depleted of its land supply. Location of the unused cropland in 1980, Solution I, is shown in Figure 5.

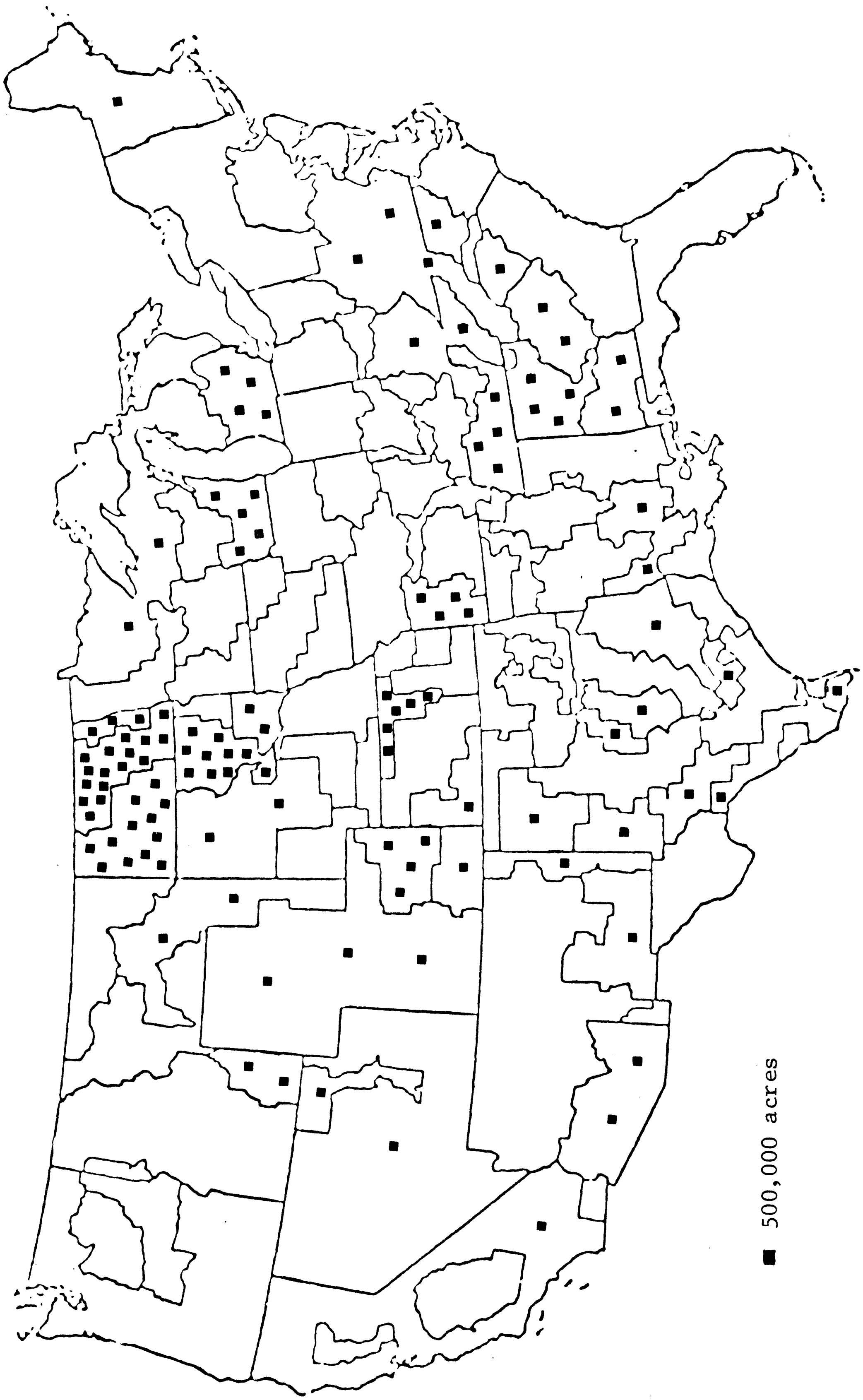
National acreages of wheat, corn, and oats as estimated for 1980, Solution I, are below the levels in 1963-65 and 1968-70 (Table 16). Estimated barley and soybean production requires more acres than the two comparison years. Grain sorghum is in between the acreages of the two comparisons.

Table 14. Estimated interregional shipments[a] of commodities for 1980, Solution I

Region[b]	Cattle	Hogs	Milk	Oils	Feeder Calves	Yearlings
	(million cwt.)				(1000 head)	
NE	-111.4	-54.4	-227.7	-27.9	269.6	0.0
AP	-26.0	-2.3	-67.7	-3.9	853.6	-684.3
SE	-18.6	-7.8	-67.1	-5.4	900.6	0.0
DL	7.5	-1.5	-26.0	-46.9	0.0	0.0
CB	36.0	83.2	-141.3	75.3	-5648.9	0.0
LK	-0.3	0.0	593.8	2.2	705.7	0.0
NP	69.5	22.9	121.2	18.6	0.0	684.3
SP	4.6	-6.8	-52.4	-0.5	4504.8	0.0
MT	39.0	-5.5	-32.8	-3.7	0.0	505.8
PC	0.0	-27.8	-100.1	-7.9	-1585.4	-505.8
	Wheat	Corn	Oats	Barley	Grain Sorghum	Oilmeals
	(million bushels)					(mil. tons)
NE	-88.5	-125.9	-15.5	0.0	-223.5	-0.6
AP	-69.7	-2.5	0.0	-8.4	-201.0	-0.6
SE	-47.0	-275.7	0.0	-10.5	-10.4	-2.0
DL	-205.8	-775.0	0.0	-4.7	-5.5	-10.5
CB	56.1	1179.0	15.5	0.0	16.1	13.6
LK	0.0	-141.3	0.0	0.0	0.0	-0.5
NP	205.2	141.3	9.1	18.9	444.5	0.8
SP	149.7	0.0	0.0	4.6	0.0	0.0
MT	0.0	0.0	0.0	0.0	0.0	0.0
PC	0.0	0.0	-9.1	0.0	-20.2	0.0

[a]Negative quantities are net imports; positive, net exports.

[b]Region codes: NE, Northeast; AP, Appalachian; SE, Southeast; DL, Delta states; CB, Corn Belt; LK, Lake states; NP, Northern Plains; SP, Southern Plains; MT, Mountain states; PC, Pacific states.



■ 500,000 acres

Figure 5. Unused cropland in 1980, Solution I

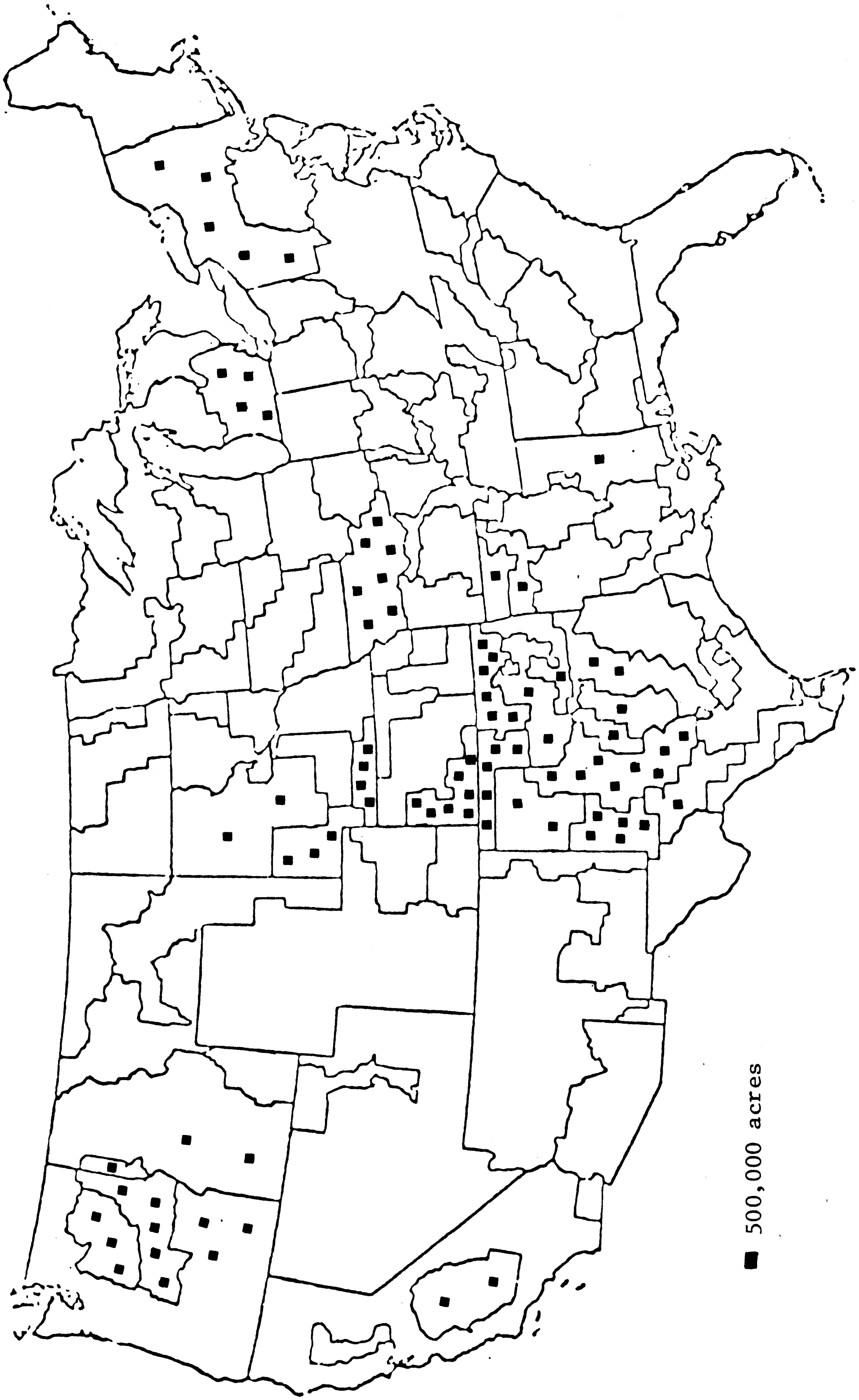


Figure 6. Acreages used in wheat production in 1980, Solution I

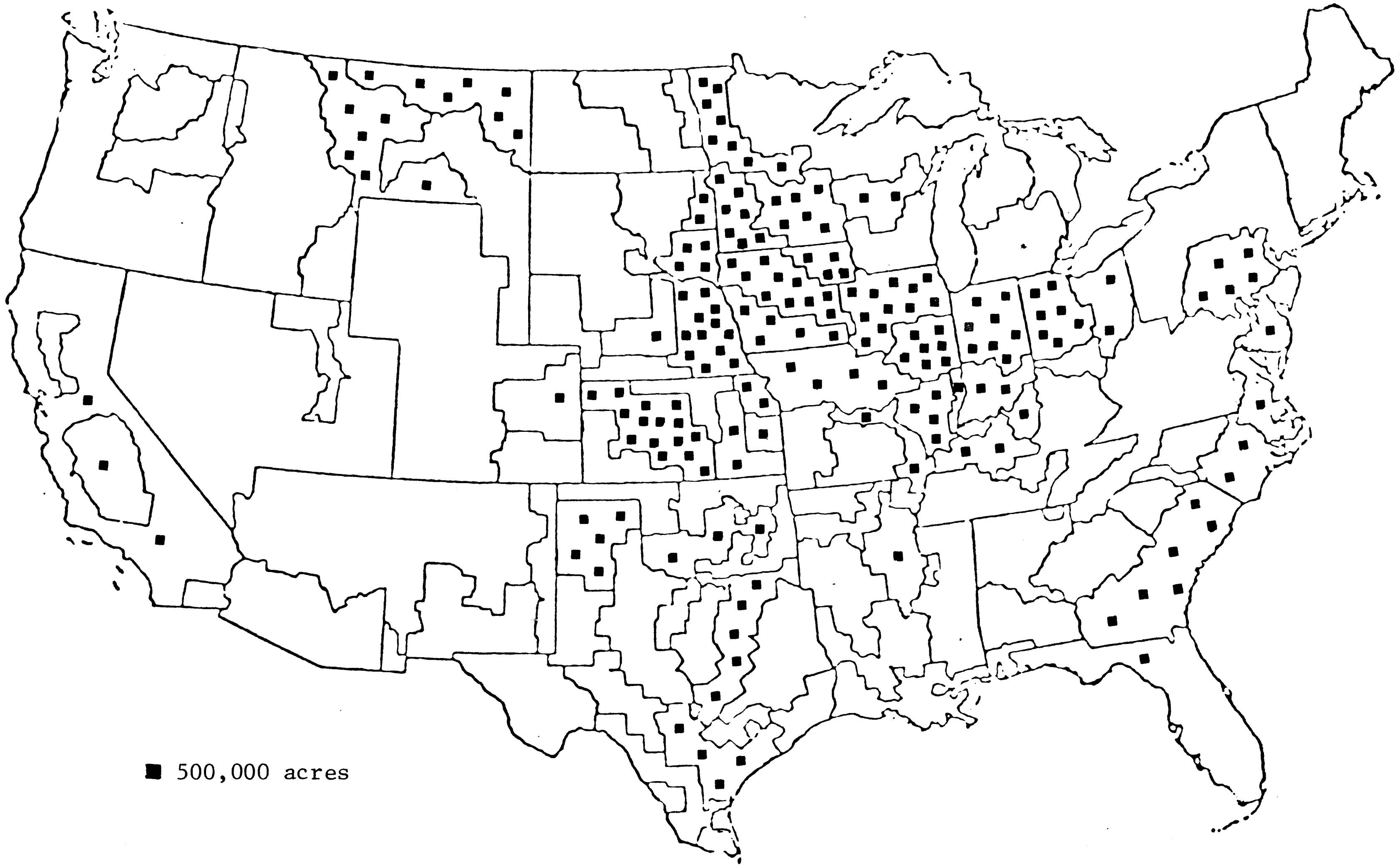


Figure 7. Acreages used in feed grain production in 1980, Solution I

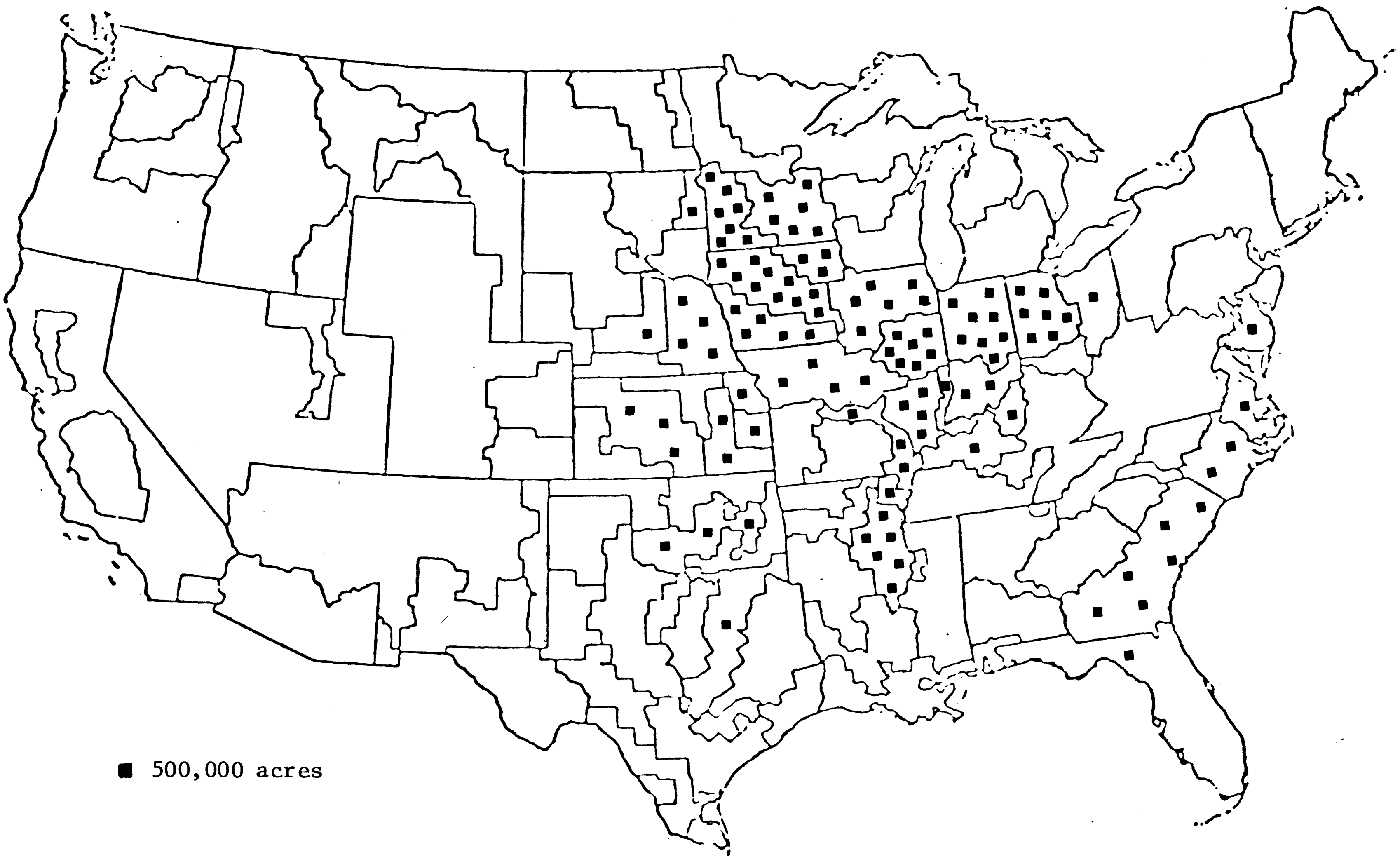


Figure 8. Acreages used in soybean production in 1980, Solution I

Production patterns for wheat, feed grains, and soybeans for 1980, Solution I, are shown in Figures 6, 7, and 8, respectively. Estimates of beef cow and fed cattle numbers for 1980, Solution I, are higher than 1965 levels, while milk cow numbers are estimated to be lower (Table 17). Hog production increases. Livestock utilization of feedstuffs is based on the lowest cost sources of TDN and protein. The feed grains are the main source of TDN and the estimated levels of livestock usage of these grains plus wheat is given in Table 18.

Estimated production costs for 1980 compared to 1964 costs for the same output behave as is expected: labor costs decrease while capital costs increase (Table 19). Soybeans and cattle and calves show the largest estimated increase in value of production for 1980 over 1963-65 and 1968-70 levels (Table 20). Dairy products decline in estimated value from 1963-65 by 45.6 percent. The other 1980 value estimates are fairly close to the comparison years.

Table 15. Estimated total cropland and cropland plus hayland available, acreage used, and percent idle in 1980, Solution I

Region[a]	Cropland			Cropland Plus Hayland		
	Available	Used	% Idle	Available	Used	% Idle
	(1000 acres)			(1000 acres)		
NE	6,773	6,332	6.5	13,936	9,129	34.5
AP	11,622	6,558	43.6	16,899	8,830	47.8
SE	11,222	7,245	35.4	12,761	8,449	33.8
DL	11,517	10,721	6.9	13,288	12,113	8.8
CB	70,500	68,465	2.8	81,567	75,249	7.8
LK	27,147	21,860	19.5	35,972	30,827	14.3
NP	62,971	37,750	40.1	71,378	42,476	40.5
SP	31,692	27,736	12.5	34,947	28,827	17.5
MT	17,870	8,822	50.6	24,866	14,873	40.2
PC	9,785	9,373	4.2	13,415	11,587	13.6
US	260,999	204,862	21.5	309,029	242,360	24.0

[a]Region codes given in Table 14.

Table 16. Estimated national acreages, production, and average yields of wheat, feed grains,[b] and soybeans for 1980 Solution I with comparisons of 1963-65 and 1968-70 average figures

Crop	1980 Solution I		
	Acreage	Production	Ave. Yield
	(10^3 A.)	(10^6 bu.)	(bu./A.)
Wheat	41,401	1,519	37
Corn	46,919	4,226	90
Oats	11,497	701	61
Barley	20,392	983	48
Grain sorghum	13,432	761	57
Soybeans	55,753	1,701	31

Crop	1963-65 Actual[a]			1968-70 Actual[a]		
	Acreage	Production	Ave. Yield	Acreage	Production	Ave. Yield
	(10^3 A.)	(10^6 bu.)	(bu./A.)	(10^3 A.)	(10^6 bu.)	(bu./A.)
Wheat	48,276	1,249	26	48,492	1,450	30
Corn	56,663	3,869	68	55,971	4,430	79
Oats	19,863	916	46	18,106	945	52
Barley	10,226	391	38	9,671	423	44
Grain sorghum	12,699	583	46	13,632	715	52
Soybeans	31,286	749	24	41,659	1,122	27

[a]Source: (U.S. Department of Agriculture, 1974).

[b]Together, corn, oats, barley, and grain sorghum, constitute feed grains.

Table 17. Estimated national livestock production for 1980 Solution I compared with 1965 levels [a]

Livestock	1980 Sol. I	1965
	(1000 head)	
Beef cows	42999	32796
Milk cows	10591	17575
Fed cattle	28916	9979
Hogs	219[b]	180[b]

[a]Source: (U.S. Department of Agriculture, 1967).

[b]Hog unit is million live cwt.

Table 18. Estimated livestock utilization of feedstuffs by crop and region for 1980, Solution I

Region[a]	Wheat	Corn	Oats	Barley	Grain Sorghum
		(million bushels)			
NE	-	-	-	104.5	223.5
AP	-	96.8	1.9	-	203.3
SE	-	343.8	10.0	-	-
DL	-	210.2	22.6	-	-
CB	-	1336.2	359.1	-	-
LK	-	380.4	109.9	269.8	-
NP	-	325.9	92.4	157.6	-
SP	-	30.0	33.6	8.7	173.6
MT	33.0	64.6	-	273.7	0.1
PC	-	-	-	-	-
US	33.0	2788.0	629.5	814.4	600.5

[a]Region codes are identified in Table 14.

Table 19. Estimated costs of production for 1980, Solution I, relative to the 1964 requirements for the same output

Cost	1980	1964[a]	'80/'64 ratio
		(million dollars[b])	
Crop Production Costs			
Labor	1,527	2,068	0.74
Capital[c]	8,743	6,765	1.29
Fertilizer[c]	1,734	1,017	1.71
Pesticides[d]	247	192	1.29
Livestock Production Costs			
Labor	1,106	1,633	0.68
Capital	6,099	4,473	1.36

[a]1964 costs were calculated from costs estimated for 1963-65 but not projected to 1980 by the indices described in the cost projection section of this chapter.

[b]1963-65 real dollars.

[c]Capital input costs do not include fertilizer costs.

[d]Capital inputs do include pesticide costs, but they are included here as a point of reference for Solution III.

Table 20. Estimated value of national production for selected commodities for Solution I compared with 1963-65 and 1968-70 average values

Commodity	1980 Sol. I[a]	1963-65 Actual[b]	1968-70 Actual[b]
		(million dollars)	
Cattle and calves	11,641	6,543	9,792
Hogs	3,252	3,227	4,501
Dairy	2,854	5,265	4,961
Wheat	1,935	1,853	2,237
Feed grains[c]	5,385	5,594	5,978
Soybeans	5,098	1,914	2,844
Sheep and lambs	260	241	199
Eggs	1,262	184	1,967
Poultry	1,535	1,245	1,604

[a]1963-65 real dollars.

[b]Source: (U.S. Department of Agriculture, 1972).

[c]Includes corn, oats, and barley for feed and food and sorghum for feed.

IV. THE IMPACT OF A NATIONAL POLICY SETTING MAXIMUM NITROGEN FERTILIZATION RATES

The origins of the chemical fertilizer industry date back to 1912 when a German scientist, Fritz Haber, succeeded in synthesizing ammonia by passing hydrogen and nitrogen gases over hot iron filings at high temperature and pressure. Ammonia was first synthesized in the United States in 1920. Chemical fertilization has since grown at a phenomenal rate (Table 21).

Environmental fears of fertilization, especially nitrogen fertilization, come from the ecological disruptions that may occur. These disruptions involve both humans, livestock, and wild animals. These fears have motivated some people to eat only organically grown food and to push for total elimination of chemical fertilizers. A realistic approach to the problem may be to eliminate the extremely high fertilization rates where pollution problems can easily occur. This part of the study deals with the effects of potential government legislation restricting, but not eliminating, the use of chemical fertilizers in crop production.

Incorporation of Fertilizer Restraints

To look at the possible effects of such a policy, the coefficients in the cropping activities of the basic model (as described in Chapter 3) are modified by the following assumptions: on corn and sorghum (both grain and silage) farmers can apply fertilizer up to 110 pounds of elemental nitrogen; on cotton, 80 pounds; on wheat, oats, and barley, 55 pounds; and on soybeans, no nitrogen fertilizer is allowed.

Table 21. Commercial fertilizer use in the United States for selected years, 1950-1974 [a]

Year	Total Fertilizer Material	Total N	Total P_2O_5	Total K_2O
		(thousand tons)		
1950	18,355	1,055	1,951	1,105
1955	24,724	1,961	2,284	1,875
1960	24,877	2,738	2,572	2,153
1965	31,836	4,639	3,512	2,835
1970	39,589	7,459	4,574	4,036
1972	41,206	8,022	4,864	4,327
1973	43,289	8,295	5,085	4,622
1974[b]	46,997	9,124	5,071	5,086

[a]Source: (Hargett, 1974).

[b]Preliminary.

Each cropping activity is checked for conformance to these assumptions. If an activity is using less than or just equal to the restraint, then no changes are made. If an activity is using more nitrogen than allowed, the amount is corrected, new yields calculated, and costs changed.

For each activity using more nitrogen than allowed, the Spillman function (equation 3.18) is recalculated. Fertilizer costs were also reestimated for any decrease.

The amounts of phosphorus and potassium also are adjusted downward with nitrogen. This procedure is based on the supposition that farmers will apply nitrogen, phosphorus, and potassium fertilizers in recommended or correct ratios. This model (Model II) is solved and its solution (Solution II) is presented in the following section.

Solution II

The obvious effect of the fertilizer restriction is lower crop yields (Table 22). Yield of grain sorghum increases slightly, but this is the only crop to show a decrease in acreage between Solution I and Solution II. Besides the direct effect of fertilizer restraints, lower yields also occur as crops are shifted among regions and to lands of lower productivity as acreages increase. Wheat and corn, at 16 and 13 percent, respectively, have the largest yield cuts. Yield losses in roughages are due solely to the indirect effect of shifting production patterns.

Consumption does not decline drastically in Solution II (Table 23). Per capita grain consumption does not change between the solutions, but consumption of livestock products decreases to a small extent under the slightly higher prices of Solution II. Demand decreases only slightly because of the inelastic food demand with respect to prices.

Roughages also have higher prices; \$20.80 per ton in Solution I vs. \$24.24 in Solution II (Table 24).[1] These price increases are because of fertilizer restrictions on corn and sorghum silage and production pattern changes that bring less productive land into production.

---

[1]See earlier qualification of price levels in terms of the fact that total costs do not incorporate fixed costs and 1964 values of the dollar are used (pages 43 and 47).

Table 22. Estimated national acreages, production, and average yields of wheat, feed grains,[a] and soybeans for 1980, Solutions II and I compared

Crop	1980 Solution II			1980 Solution I		
	Acreage (10^3 A.)	Production (10^6 bu.)	Ave. Yield (bu./A.)	Acreage (10^3 A.)	Production (10^6 bu.)	Ave. Yield (bu./A.)
Wheat	48,544	1,485	31	41,401	1,519	37
Corn	50,400	3,950	78	46,919	4,226	90
Oats	13,356	773	58	11,497	701	61
Barley	29,729	1,359	46	20,392	983	48
Grain sorghum	11,068	636	57	13,432	761	57
Soybeans	56,267	1,719	31	55,753	1,701	31
Cotton	9,584	5,868[b]	612[c]	7,545	5,892[b]	781[c]

[a]Includes corn, oats, barley, and grain sorghum.

[b]Million pounds of cotton.

[c]Pounds of cotton.

Table 23. Estimated national equilibrium prices, total domestic consumption, and per capita consumption for selected, on-the-farm commodities for 1980, Solutions II and I compared

Commodity	1980 Solution II			1980 Solution I		
	Price[b]	Domestic Consumption	Per Capita Consumption	Price[b]	Domestic Consumption	Per Capita Consumption
	($/cwt.)	(mil. cwt.)	(lb.)	($/cwt.)	(mil. cwt.)	(lb.)
Cattle	27.5	448	195.5	27.3	449	196.1
Calves	20.7	2	0.8	19.4	2	0.8
Hogs	15.7	217	95.0	14.9	221	96.6
F. Milk	2.5	483	210.9	2.4	484	211.4
M. Milk	2.1	805	351.7	2.0	821	358.5
Oil	20.0	94	41.0	22.1	89	39.0
Sheep & lambs	22.2	12	5.1	21.8	12	5.2
Eggs[a]	21.8	61	26.4	20.7	61	26.6
Poultry	9.4	169	73.8	9.0	170	74.2
Cotton	21.3	39	17.0	21.5	39	17.0
	($/bu.)	(mil. bu.)	(bu.)	($/bu.)	(mil. bu.)	(bu.)
Wheat	1.44	485	2.1	1.30	486	2.1
Corn	.96	488	2.1	.86	488	2.1
Oats	.51	61	0.3	.46	61	0.3
Barley	.87	133	0.6	.76	133	0.6

[a]Unit on eggs is dozen to give the appropriate column headings: ¢/doz., mil. doz., and doz.

[b]Weighted average of regional prices with production as weights. Measured in 1963-65 real dollars.

Table 24. Estimated equilibrium prices[a] for selected, on-the-farm commodities for 1980, Solutions II and I compared

Region[b]	Cattle Sol. II	Cattle Sol. I	Hogs Sol. II	Hogs Sol. I	Wheat Sol. II	Wheat Sol. I	Corn Sol. II	Corn Sol. I	Barley Sol. II	Barley Sol. I	Grain Sorghum Sol. II	Grain Sorghum Sol. I
	($/cwt.)				($/bu.)				($/bu.)			
NE	28.4	28.2	16.2	15.4	1.43	1.34	1.08	1.00	0.88	0.80	1.05	0.96
AP	28.2	28.1	15.9	15.1	1.41	1.32	1.07	.97	.87	.85	1.04	.95
SE	27.7	27.5	15.5	14.7	1.37	1.29	.96	.86	.84	.76	.96	.87
DL	27.4	27.2	15.4	14.6	1.48	1.38	.95	.85	.86	.78	.94	.84
CB	27.1	27.0	14.4	13.6	1.37	1.13	.78	.68	.82	.72	.81	.72
LK	27.5	27.3	14.7	13.8	1.22	1.18	.96	.86	.78	.70	.94	.84
NP	26.9	26.7	14.8	14.0	1.08	0.99	.75	.65	.61	.52	.77	.67
SP	26.8	26.6	15.6	14.8	1.28	1.18	.87	.77	.71	.64	.85	.76
MT	26.5	26.3	16.1	15.3	0.97	0.89	.83	.81	.68	.67	.81	.80
PC	26.4	25.8	17.0	16.1	1.77	1.52	1.11	1.13	1.03	.83	1.21	1.12
US	27.5	27.3	15.7	14.9	1.44	1.30	0.96	0.86	0.87	0.76	0.96	0.88
	Feeder Calves[c]		Yearlings[d]		Roughages		Oilmeal		Oil		Soybeans	
	($/head)				($/ton)		($/cwt.)		($/cwt.)		($/bu.)	
NE	142.44	141.88	204.46	203.13	26.93	26.59	193.95	175.95	20.2	22.5	3.07	3.23
AP	145.29	144.73	197.69	196.36	33.51	33.47	187.95	169.95	20.2	22.5	3.04	3.20
SE	146.39	145.46	193.80	192.47	31.51	31.51	166.65	148.65	19.9	22.2	2.91	3.07
DL	149.07	148.23	191.70	190.37	24.43	24.44	165.75	147.75	19.9	22.2	2.90	3.06
CB	150.96	150.40	197.75	196.28	19.64	19.56	135.85	117.85	19.0	21.3	2.67	2.84
LK	148.52	147.96	193.64	192.17	20.04	19.81	177.85	159.85	19.0	21.3	2.86	3.02
NP	150.15	149.61	191.12	189.79	16.31	15.65	130.45	112.45	18.9	21.2	2.63	2.80
SP	146.56	146.00	190.33	188.86	22.92	22.78	180.45	161.60	19.8	22.1	2.96	3.12
MT	148.25	146.82	189.70	188.23	21.61	21.61	178.60	163.50	19.9	22.2	2.96	3.14
PC	153.45	152.89	201.95	200.48	25.45	25.28	193.30	173.00	20.2	22.5	3.07	3.22
US	148.11	147.10	195.21	193.81	24.24	20.80	159.20	141.25	19.7	22.1	2.83	3.00

[a] 1963-65 real dollars.

[b] Region codes; NE, Northeast; AP, Appalachian; SE, Southeast; DL, Delta states; CB, Corn Belt; LK, Lake states; NP, Northern Plains; SP, Southern Plains; MT, Mountain states; PC, Pacific states.

[c] 400 pounds per head.

[d] 700 pounds per head.

On a per acre basis, fertilizer costs in Model II decrease while other costs remain constant. Total national fertilizer costs decrease from $1,734 million in Solution I to $1,246 million in Solution II (Table 25) even though there is an increase in the total acreage used for crop production. The decrease in fertilizer costs is offset by labor and capital costs which increase because of the greater acreage used in production. Total costs are thus approximately the same in both solutions.

Because the domestic prices increase, net internatonal imports increase for cattle and hogs in Solution II (Table 26). (Net exports of wheat, corn, oil, and oilmeals are set at the same trend levels in both models.)

On a national level 8.2 percent of the available cropland not used for crops moves into production between Solution I and Solution II (Table 27). Location of available cropland not used for crops in Solution II is shown in Figure 9.

Only the Delta region has more unused cropland in Solution II than in Solution I. Other regions have greater relative advantages in production under fertilizer restrictions.

When the fertilization rate is limited, relative advantages in crop and livestock production shift among regions in the model. The Northeast region produces wheat in Solution I but shifts to corn in Solution II (Table 28, and Figures 10 and 11). This decrease in wheat production is accompanied by an increase in wheat imports by the region (Table 29). The Delta and Southern Plains experience declines in production and increases

Table 25. Estimated national costs of crop production for 1980, Solutions II and I compared

Cost	Sol. II	Sol. I
	(million dollars)[a]	
Labor	1,588	1,527
Fertilizer[b]	1,246	1,734
Capital	9,215	8,742
Total	12,048	12,002

[a]1963-65 real dollars.

[b]Fertilizer is a capital cost, but it is not included in that category in this study.

Table 26. Estimated net international commercial exports[a] for selected commodities on national level, Solutions II and I compared

Commodity	Unit	1980 Sol. II	1980 Sol. I
		(million units)	
Cattle	lb.	-2,401	-2,377
Hogs	lb.	-243	-230
Wheat	bu.	1,000	1,000
Corn	bu.	950	950
Oils	lb.	10,805	10,805
Oilmeals[b]	tons	20	20

[a]Negative terms denote net imports

[b]Includes soybean and cottonseed meals.

Table 27. Estimated total cropland and cropland plus hayland available, acreage used, and percent idle in 1980, Solutions II and I compared

Region[a]	Cropland				Cropland Plus Hayland			
	Available	Sol. II		Sol. I	Available	Sol. II		Sol. I
		Used	% Idle	% Idle		Used	% Idle	% Idle
	(1000 acres)				(1000 acres)			
NE	6,773	6,481	4.3	6.5	13,936	9,271	33.5	34.5
AP	11,622	6,581	43.4	43.6	16,899	9,057	46.4	47.8
SE	11,222	8,650	22.9	35.4	12,761	9,923	22.2	33.8
DL	11,517	10,443	9.3	6.9	13,288	11,834	10.9	8.8
CB	70,400	68,465	2.8	2.8	81,567	75,315	7.7	7.8
LK	27,147	22,196	18.2	19.5	35,972	31,118	13.5	14.3
NP	62,971	54,913	12.8	40.1	71,378	58,777	17.7	40.5
SP	31,792	28,089	11.4	12.5	34,947	29,226	16.4	17.5
MT	17,870	11,108	37.8	50.6	24,866	17,124	31.1	40.2
PC	9,785	9,404	3.9	4.2	13,415	12,047	10.2	13.6
US	260,998	226,330	13.3	21.5	319,028	263,691	17.4	24.0

[a]Region codes are identified in Table 24.

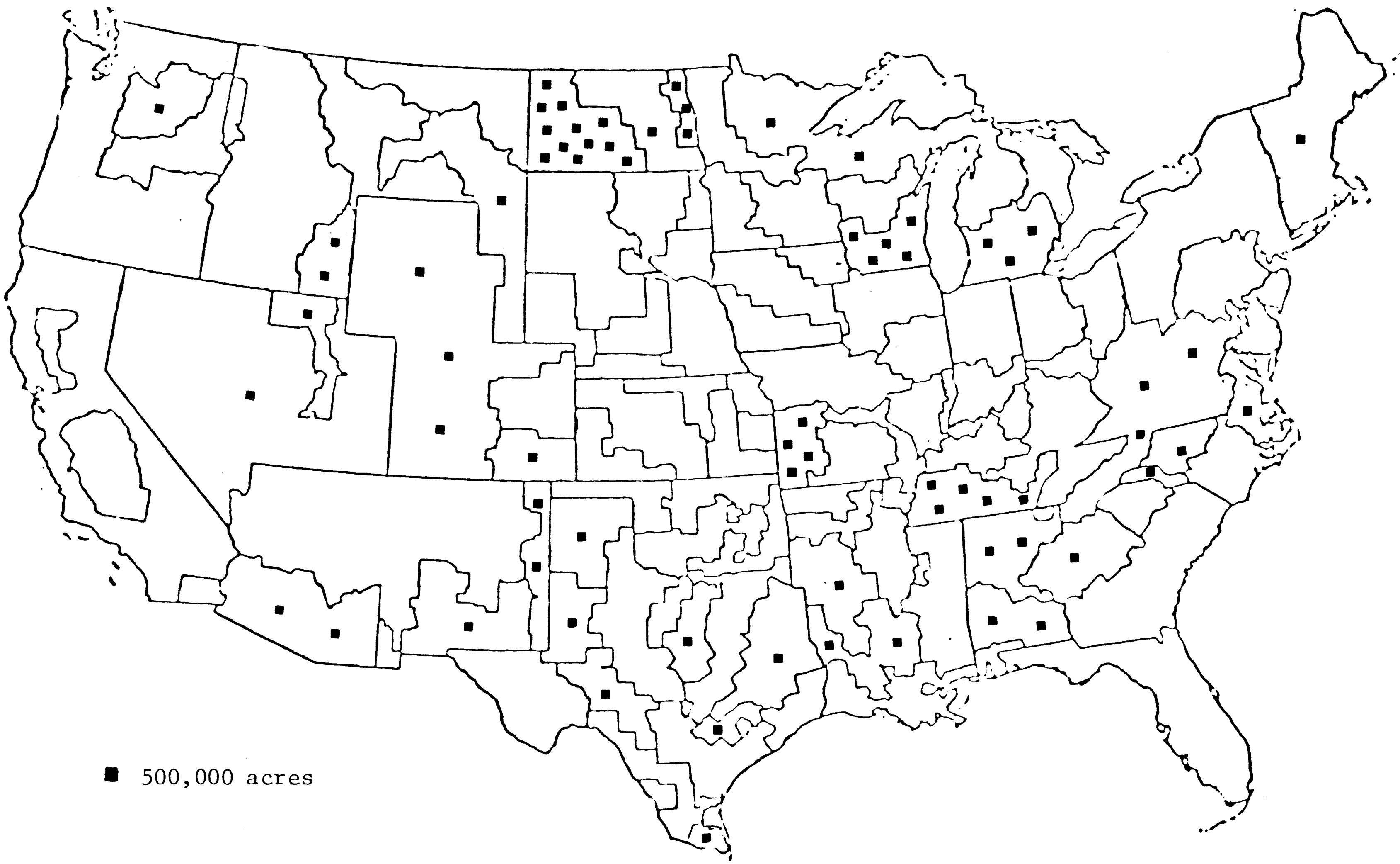


Figure 9. Unused cropland in 1980, Solution II

Table 28. Estimated acreage and production of selected crops by region for 1980, Solutions II and I compared

Region[a]	Wheat				Corn				Oats			
	Solution II		Solution I		Solution II		Solution I		Solution II		Solution I	
	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production
	(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 bushels)			
NE	-	-	2,435	103,422	2,963	268,243	527	38,911	19	893	19	893
AP	-	-	-	-	2,641	186,741	2,746	218,602	133	7,087	138	7,403
SE	-	-	-	-	2,668	142,812	3,212	188,045	337	12,521	415	15,440
DL	1,018	28,592	1,308	47,746	335	14,874	330	16,544	319	21,943	319	24,951
CB	1,078	43,476	3,449	161,895	28,081	2,353,659	26,984	2,733,929	5,398	372,003	5,464	385,006
LK	2,285	74,886	1,878	74,855	4,151	322,105	4,183	334,762	1,853	122,797	1,871	123,998
NP	17,234	498,111	7,666	216,277	6,510	400,795	6,253	478,330	4,159	195,342	2,140	102,908
SP	17,086	524,847	16,789	566,020	1,251	64,561	1,242	64,822	1,097	37,961	1,090	37,740
MT	3,414	95,659	1,428	53,516	1,164	121,242	737	85,165	42	2,575	40	2,579
PC	6,429	219,754	6,449	295,078	636	74,578	704	67,220	-	-	-	-
US	48,544	1,485,321	41,401	1,518,808	50,400	3,949,602	46,919	4,226,323	13,356	773,121	11,497	700,917
	Barley				Roughage[b]				Cotton			
	(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 lb.)			
NE	2,492	145,406	2,343	140,650	3,174	7,689	3,182	7,709	-	-	-	-
AP	951	52,379	103	5,390	2,841	6,523	2,586	5,921	-	-	642	346
SE	23	889	30	1,223	1,433	3,885	1,377	3,729	2,680	1,254	-	-
DL	7	288	7	288	1,497	3,457	1,498	3,461	4,910	2,993	4,910	3,436
CB	449	22,537	445	22,698	7,721	26,618	7,648	26,639	682	399	682	399
LK	5,535	290,510	5,535	294,007	11,473	37,458	11,486	37,277	-	-	-	-
NP	12,345	515,129	3,987	179,618	10,650	26,509	10,385	30,299	-	-	-	-
SP	759	20,791	758	22,446	2,077	10,557	2,011	10,468	-	-	-	-
MT	6,288	273,976	6,407	279,363	6,760	17,669	6,805	17,692	-	-	-	-
PC	880	36,895	777	37,144	3,223	15,656	2,777	13,674	1,312	1,222	1,312	1,711
US	29,729	1,358,799	20,392	982,826	50,847	156,019	49,753	156,867	9,584	5,868	7,545	5,892

[a]Region codes are identified in Table 24.

[b]Includes silage, hay, and wild hay.

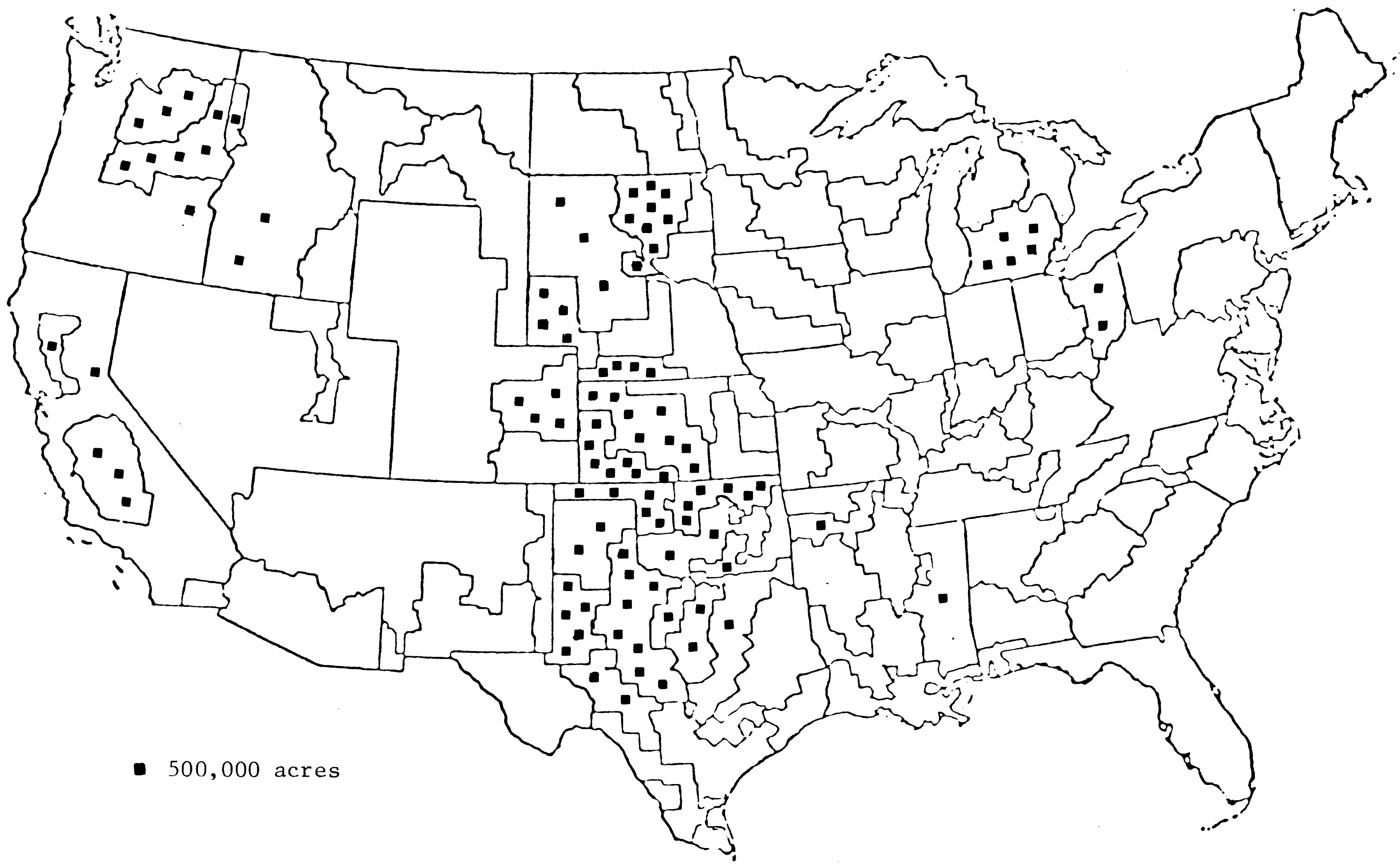


Figure 10. Acreages used in wheat production in 1980, Solution II

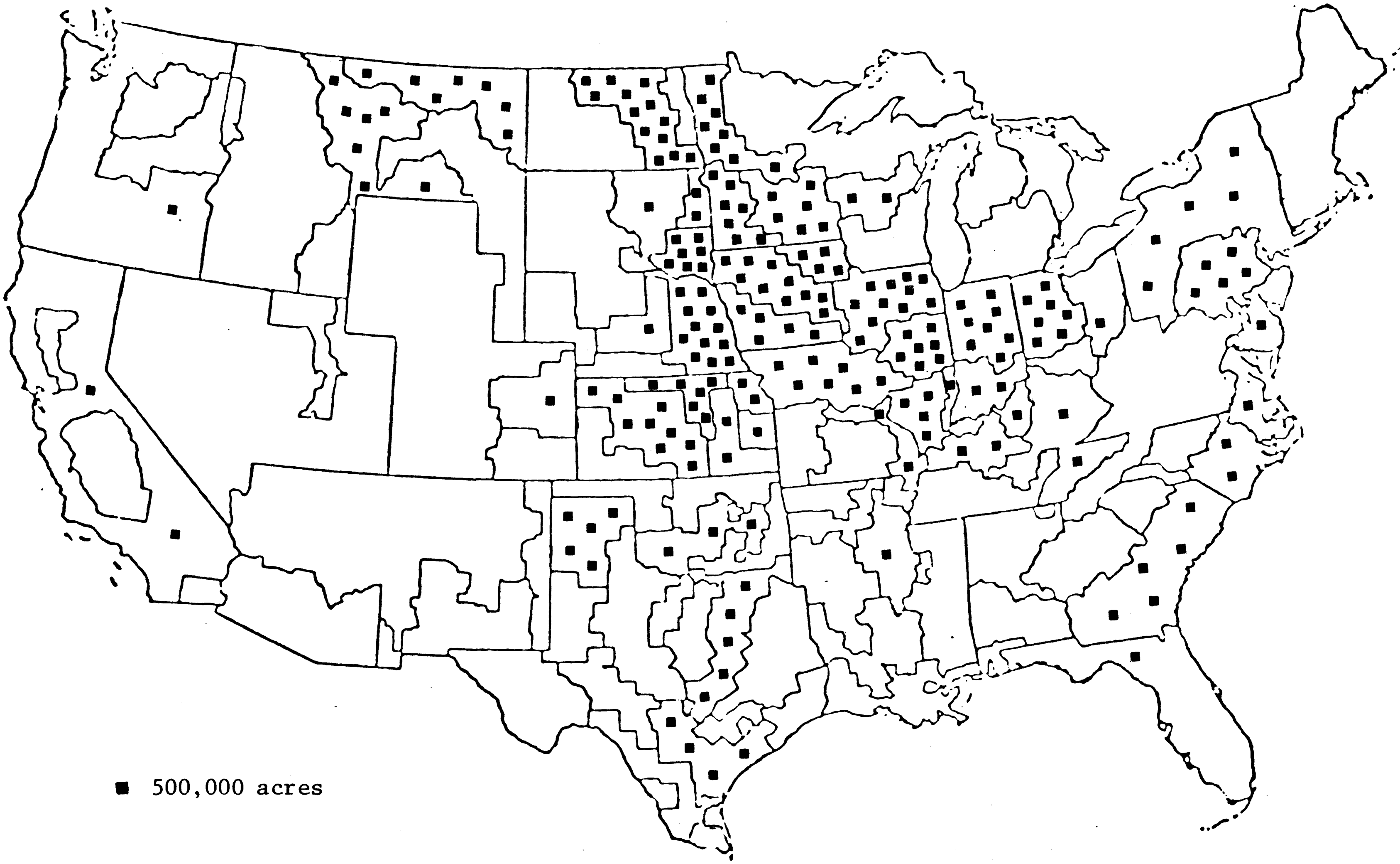


Figure 11. Acreages used in feed grain production in 1980, Solution II

in regional wheat imports between Solutions I and II while the Corn Belt changes from a net exporter to a net importer of wheat. The Northern Plains increase wheat production from 216 to 498 million bushels and increase interregional exports by the same quantity. The Mountain states export 75 million bushels of wheat to the Pacific states in Solution II but not in Solution I. The decrease in yield, the relative increase in labor and capital costs, and constant transportation costs cause the Mountain states to bring almost 2 million acres into wheat production for export to the Pacific states. The Pacific states then use this "freed" land to increase their acreage of feed grains.

Table 29. Estimated interregional shipments[a] of selected grains for 1980, Solutions II and I compared

Region[b]	Wheat		Corn		Barley		Grain Sorghum	
	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I
	(million bu.)							
NE	-192	-89	0	-126	0	0	-120	-224
AP	-70	-70	0	-3	0	-8	-180	-201
SE	-47	-47	-323	-276	-11	-11	-11	-10
DL	-225	-206	-777	-775	-5	-5	-6	-6
CB	-62	56	910	1179	0	0	18	16
LK	0	0	-151	-141	0	0	0	0
NP	487	205	342	141	11	19	317	445
SP	109	150	0	0	5	5	0	0
MT	75	0	0	0	0	0	0	0
PC	-75	0	0	0	0	0	-20	-20

[a]Negative quantities are net imports; positive, net exports.

[b]Region codes are identified in Table 24.

In shifting land from wheat to corn, the Northeast region no longer imports corn under Solution II. The Southeast region shifts from corn to roughage and, especially, cotton. It then increases its imports of corn in Solution II. The Corn Belt shifts some wheat land to corn under Solution II but still has a decline in total production from 2,734 million bushels in Solution I to 2,354 million bushels in Solution II. The Corn Belt also decreases its interregional corn exports by 270 million bushels. Although the Northern Plains increases corn acreage but decreases total production, it still ships 200 million bushels more corn to the other regions than under Solution I. The Mountain and Pacific regions have modest shifts in corn acreage, production, and trade. Nationally, corn acreage increases by 3.5 million acres, as more land is used for this crop, but production decreases by 277 million bushels due to lower per acre yields.

National oats production increases by 2 million acres and 72 million bushels between Solutions I and II. Increases occur in the Northern Plains while the Southeast, Delta states, and Corn Belt decrease production. Barley is also in greater demand as feed in Model II. Nationally, barley production increases by 376 million bushels. The Appalachian states and Northern Plains increase production while the Lake and Mountain states and Southern Plains decrease production.

Roughage production increases somewhat with the largest shifts occurring in the Northern Plains and Pacific regions. Cotton acreage increases at the national level, but production remains fairly constant. The Appalachian region shifts some out of cotton production into feed grains, Solution II. The Southeast produces 1.3 billion pounds under Solution II but none under Solution I, shifting from feed grains to do so.

Nationally, crop production costs remain fairly constant between Solutions I and II (Table 30). The Corn Belt has a decline in total crop costs because fertilizer costs are $350 million less in Solution II than in Solution I.

Previously, we noted that demand for livestock products decreased in Solution II (Table 23). Hence, except for beef cow production, livestock production also declined (Table 31). Yearling slaughter increased in Solution II from Solution I because of the higher costs of the feedstuffs required to finish animals.

The nitrogen fertilizer restrictions causes oats and barley to be substituted for corn and grain sorghum in livestock rations (Table 32). This is an "imperfect substitution" because the use of corn and sorghum declines by 401 million bushels while the use of oats and barley increases by 1,169 million bushels.

Farm Income and Consumer Food Costs

As compared to Solution I, Solution II has higher prices, lower yields, less production, lower consumption levels, and more land in crops. But what are the effects on farm income and consumers' food costs?

Changes in value of crop and livestock production are used as an estimate of changes in farm income. Because demand is inelastic, the fertilizer limitation causes the value of agricultural production in total to increase (Tables 33 and 34). Production value increases for all

Table 30. Estimated costs of crop production for 1980, Solutions II and I compared

Region[a]	Solution II				Solution I			
	Total	Labor	Fertilizer[b]	Capital	Total	Labor	Fertilizer[b]	Capital
				(million dollars[c])				
NE	621	82	78	461	524	64	62	398
AP	577	51	63	463	646	69	99	478
SE	476	37	75	364	482	38	52	393
DL	974	140	59	775	1,025	141	101	783
CB	3,597	492	403	2,701	3,891	487	750	2,653
LK	1,326	189	147	990	1,342	187	173	982
NP	2,053	256	208	1,588	1,724	217	233	1,274
SP	1,144	129	110	905	1,152	127	135	890
MT	591	86	25	480	522	76	23	423
PC	691	126	77	488	694	121	106	468
US	12,048	1,588	1,246	9,215	12,002	1,527	1,734	8,742

[a]Region codes are identified in Table 24.

[b]Fertilizer is a capital cost, but it is not included in the capital cost category in this study.

[c]1963-65 real dollars.

Table 31. Estimated regional livestock production patterns for 1980, Solutions II and I compared

Region[a]	Beef Cows		Milk Cows		Fed Cattle		Hogs	
	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I
			(1000 head)				(1000 live cwt.)	
NE	276	276	1,077	1,080	296	296	4,835	4,835
AP	1,646	1,328	413	414	178	178	12,377	15,871
SE	3,219	3,219	390	391	372	372	10,419	10,419
DL	3,554	3,554	191	192	160	160	5,620	5,620
CB	5,837	5,837	776	778	9,653	9,653	12,231	12,231
LK	1,233	1,233	5,388	5,285	1,602	1,921	18,569	18,967
NP	7,923	7,923	668	1,396	5,883	5,883	27,707	27,707
SP	10,265	10,265	268	269	2,079	2,079	7,344	7,344
MT	6,736	6,736	167	167	4,223	4,223	3,203	3,203
PC	2,628	2,628	983	620	3,945	4,151	2,700	2,700
US	43,317	42,999	10,321	10,591	28,391	28,916	215,004	218,896

[a]Region codes are identified in Table 24.

Table 32. Estimated livestock utilization of feed grains by region for 1980, Solutions II and I compared

Region[a]	Corn		Oats		Barley		Grain Sorghum	
	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I	Sol. II	Sol. I
				(million bushels)				
NE	104	-	-	-	110	105	120	224
AP	63	97	2	2	39	-	182	203
SE	346	344	7	10	-	-	-	-
DL	211	210	20	23	-	-	-	-
CB	1,225	1,336	346	359	-	-	-	-
LK	378	380	109	110	226	270	-	-
NP	48	326	185	92	501	158	-	-
SP	30	30	34	34	7	9	174	174
MT	101	65	-	-	268	274	-	-
PC	7	-	-	-	-	-	-	-
US	2,512	2,788	702	630	1,911	814	476	601

[a]Region codes are identified in Table 24.

commodities except soybeans where the value of oil declines. The value of sheep and lambs remains the same between Solution I and Solution II. (The values in Tables 33 and 34 are based on 1963-65 average value of the dollar. Increased to 1975 dollar values, they would be considerably higher but would still bear the same relative magnitudes within either solution or between solutions.)

Comparison of consumer food costs at the farm level are made by calculating the cost of the desired commodities in both solutions (Table 35). Solution II has a 1.4 percent increase in total consumer food costs over Solution I. Using the U.S. Department of Commerce's (1975) consumer price index, the total consumer food costs in the U.S. are inflated to $209.21 and $206.28 in May, 1975, for Solutions II and I, respectively, for commodities endogenous to the model.

Table 33. Estimated value of national production for selected commodities, Solutions II and I compared

Commodity	1980 Solution II	1980 Solution I
	(million 1963-1965 dollars)	
Cattle and calves	11,706	11,641
Hogs	3,369	3,252
Dairy	2,906	2,854
Wheat	2,134	1,935
Feed grains[a]	5,955	5,385
Soybeans	4,870	5,098
Sheep and lambs	260	260
Eggs	1,320	1,262
Poultry	1,586	1,535

[a]Includes corn, oats, and barley for feed and food, and grain sorghum for feed.

Table 34. Estimated value of production of selected commodities by region for 1980, Solutions II and I compared.

Region[a]	Cattle and Calves Sol. II	Cattle and Calves Sol. I	Hogs Sol. II	Hogs Sol. I	Eggs Sol. II	Eggs Sol. I
			(million dollars[b])			
NE	3,349	3,331	940	911	356	340
AP	989	984	283	274	115	110
SE	977	972	276	267	114	109
DL	387	384	108	104	45	44
CB	2,119	2,106	554	532	223	213
LK	1,050	1,044	273	262	112	107
NP	262	258	71	68	30	28
SP	770	765	216	209	88	84
MT	482	479	138	133	55	53
PC	1,323	1,318	509	492	182	174
US	11,706	11,641	3,369	3,252	1,320	1,262

Region[a]	Wheat Sol. II	Wheat Sol. I	Corn Sol. II	Corn Sol. I	Oil Sol. II	Oil Sol. I
NE	273	257	178	165	626	670
AP	98	92	133	121	275	298
SE	65	61	115	102	312	339
DL	375	349	555	494	1,323	1,474
CB	144	120	171	148	675	741
LK	91	88	92	83	269	294
NP	12	11	8	7	40	43
SP	534	491	30	27	125	133
MT	20	18	17	17	77	81
PC	522	448	75	76	262	278
US	2,134	1,935	1,374	1,240	3,984	4,351

[a]Region codes are identified in Table 24.

[b]1963-65 real dollars.

Table 35. Estimated total farm-level cost of desired commodities for consumers by region for 1980, Solutions II and I compared[a]

Region[b]	1980 Sol. II	1980 Sol. I
	(dollars[c])	
NE	120.24	118.81
AP	106.26	105.00
SE	103.52	102.19
DL	100.95	99.64
CB	112.25	110.40
LK	111.42	110.00
NP	103.46	101.57
SP	105.78	104.41
MT	106.43	105.40
PC	119.81	117.69
US	112.84	111.26

[a]Calculated from per capita consumption and regional price estimates.

[b]Region codes are identified in Table 24.

[c]1963-65 real dollars.

V. THE IMPACT OF REMOVAL OF CERTAIN INSECTICIDES

Insecticides represent a chemical input that has allowed production in areas previously infested by insects and also reduced crop yield losses in regularly cropped areas. Insecticide use has grown steadily (Table 36) and makes up the major portion of total pesticide use in the United States. In earlier years, lead, mercury, and arsenic were the base chemicals used. However, these have been shown to be environentally undesirable due to their persistence. DDT and similar isotopes have also been taken off the market because of their persistence.

Table 36. Insecticide use in the United States[a]

Year	Sales
	(million pounds)
1962	442
1963	435
1964	445
1965	473
1966	502
1967	489
1968	498
1969	502

[a]Source: U.S. Tariff Commission as listed in Metcalf (1971).

This section of the study examines the production effects of removal of four organochlorine insecticides: aldrin, dieldrin, chlordane, and heptachlor. Of these four, the use of aldrin and dieldrin has been suspended by the Food and Drug Administration (FDA) and the use of chlordane and heptachlor is being considered for suspension by the FDA. Persistence, or length of active life in the soil, is the major environmental problem with this type of insecticide.

The substitutions allowed are three organophosphate insecticies and one carbamate insecticide which have a shorter persistence in the soil (Figure 12). These are imperfect substitutions, however, because the substitutes are not as effective against some important pests. Lack of effectiveness is partly caused by the short residual life of these compounds. The yield losses and cost increases resulting from this imperfect substitution are the causes of the effects that this section of the study estimates.

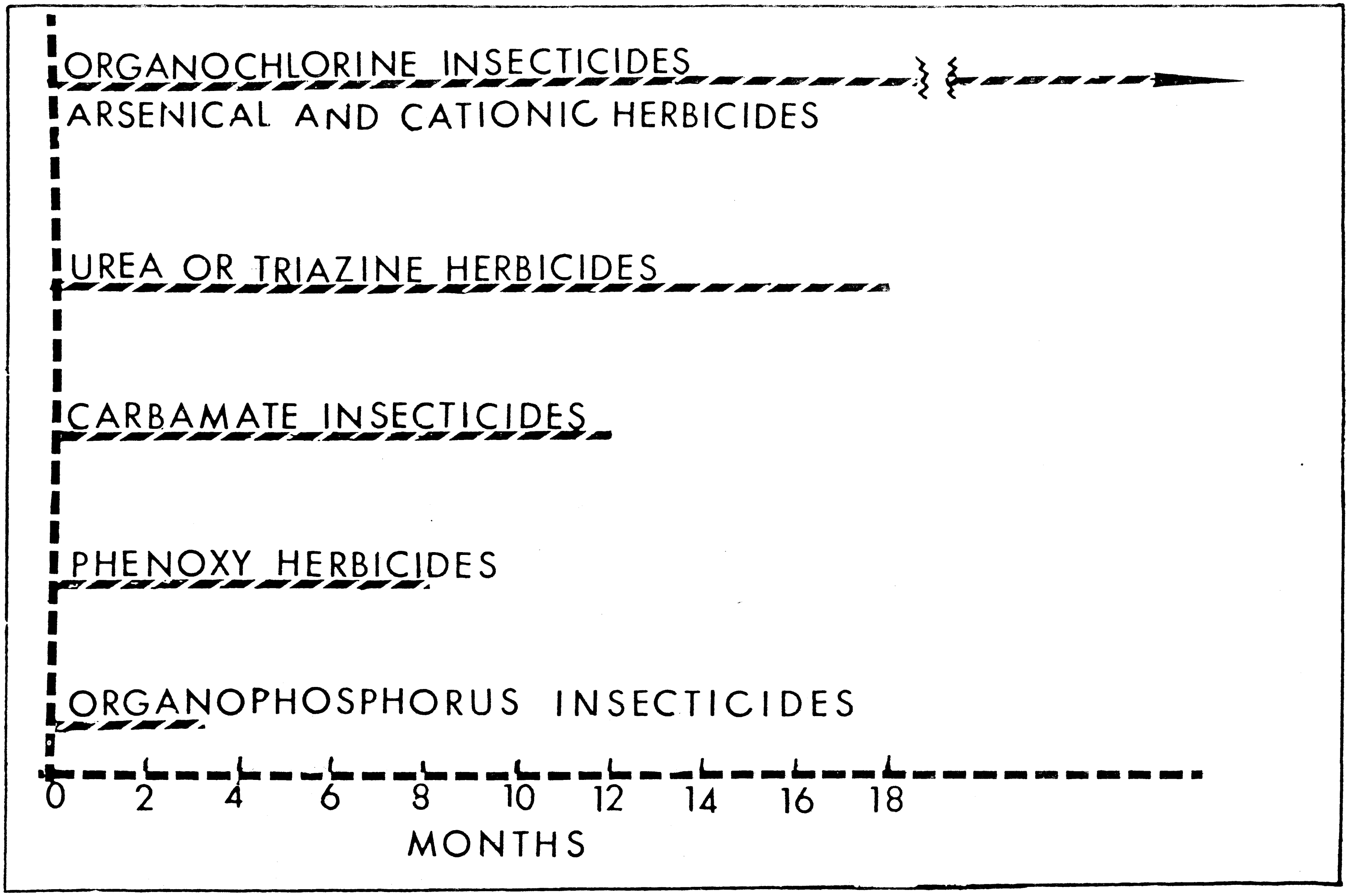


Figure 12. Maximum persistence of classes of pesticides in soils under moderate climatic conditions (Stewart, 1975)

Incorporation of Insecticide Restrictions

More than 90 percent of aldrin, dieldrin, chlordane, and heptachlor is used on corn acreages in three USDA regions (Corn Belt, Lake States, and Northern Plains) (Delvo, 1974; Andrilenas, 1974). Because of this fact and the lack of reliable data for other areas, we have restricted our yield losses and cost increases to the states in the three USDA regions: Ohio, Indiana, Illinois, Iowa, Missouri, Michigan, Wisconsin, Minnesota, Kansas, Nebraska, North Dakota and South Dakota (Figure 13).

The substitutes and their percentage share of the substitute mix are: Thimet (40%), Mocap (5%), Dasanit (15%), and Furadan (40%).[1] Using the 1971-72 price list and this mix of insecticides at the recommended rates, the increased cost per acre over the organochlorine insecticides are determined for each of these USDA regions:

USDA Region	Increased cost (1963-65 dollars)
Corn Belt	$2.243
Lake States	$0.377
Northern Plains	$0.265

These costs (in 1963-65 dollars) are the blanket cost increases that are added to every corn and corn silage activity in the specified regions. In addition to the blanket cost increase, there are costs and yield losses that occur with different degrees of insect infestation. Cost and yield effects are calculated by the following assumptions.

[1]These substitutes and their mix and the following average yield losses and cost increases were developed by Drs. Harold Stockdale and Jerold Dewitt, Entomology Department, Iowa State University, in discussions with Gary Vocke, Staff Economist, Center for Agricultural and Rural Development, Iowa State University.

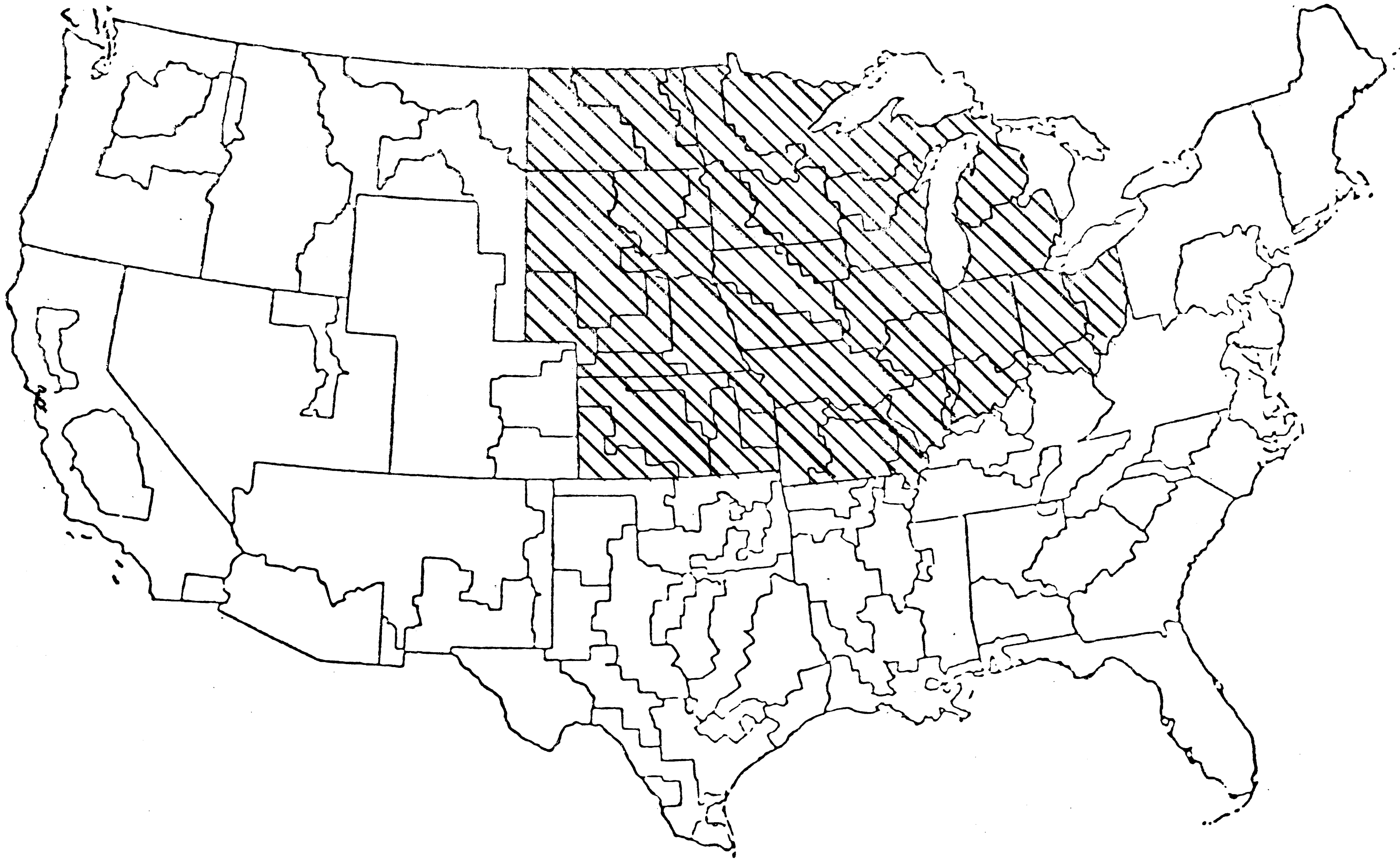


Figure 13. Area assumed afflicted by removal of aldrin, dieldrin, chlordane, and heptachlor insecticides

There is an insect complex which attack corn and corn silage during the first year following a meadow-type crop (wheat, nonlegume and legume hay, oats, and barley). The assumptions[1] are: (1) 20 percent of the first year corn will be affected by this complex and will suffer a yield loss of 10 percent without any insecticide applied, (2) the substitute chemicals are assumed to be 50 percent effective against the complex (i.e., the yield losses resulting from no insecticide application are reduced by half when the substitutes are used). To obtain the yield loss for each activity, the following equation is used:

$$\begin{pmatrix}\text{Yield loss due to} \\ \text{first year complex} \\ \text{(bu. or tons)}\end{pmatrix} = Y_I \times F \times F_A \times L_1 \times S \qquad (5.1)$$

where

Y_I = Yield in Model I (bus. or tons)

F = percent of first year corn in activity

F_A = percent of first year corn affected = 20 percent

L_1 = percent yield loss without insecticides = 10 percent

S = percent effectiveness of substitutes = 50 percent.

For example, if the present yield of corn in an activity was 100 bushels per acre and if 50 percent of the corn in this activity is first-year corn (two years of corn - 1 year of alfalfa hay), there would be a yield loss of 0.5 bushels per acre or a new yield of 99.5 bushels per acre.

The cutworm and the low wetlands insect complex cause problems when the organochlorine insecticides are removed. The assumed percentage

---

[1] See footnote on page 80.

of wetland acres infested by this complex varies among USDA regions.[1] These percentages of infestations are: Corn Belt, 16 percent; Lake States, 15 percent; and Northern Plains, 4 percent. The percentage on infestation in all cropland in a production area is found by using the percent of wetlands in that area and the infestation for the appropriate USDA region.

It is assumed that 25 percent of the acres infested will be replanted and that 75 percent of these acres will not be replanted.[2] Those acres replanted will suffer from a yield loss because of timeliness and a cost increase because of replanting. The yield loss is determined by length of growing season and whether the land is irrigated or not. The assumed percentage losses are:

Area	Timeliness[3] Yield loss
North of Iowa	28%
Iowa and East	22%
South of Iowa	18%
West of Iowa	18%
Irrigated Land	28%

(These losses include the estimated need for new seed.) The cost increase is because of additional labor and machinery needed to replant. Each acre that is replanted is estimated to incur 10 percent more in

[1]See footnote on page 80.

[2]See footnote on page 80.

[3]See footnote on page 80.

machinery cost and to use 20 percent more labor.[1] The equations used for the infested wetland acres are:

$$\text{Timeliness yield loss (in bu. or tons)} = Y_I \times L_2 \times R \times W \times I \qquad (5.2)$$

$$\text{Machinery cost increase} = C_I \times L_3 \times R \times W \times I \qquad (5.3)$$

$$\text{Labor manhours increase} = L_I \times L_4 \times R \times W \times I \qquad (5.4)$$

where:

Y_I = Yield in Model I (bu. or tons),

C_I = Machinery cost in Model I (1963-65 dollars),

L_I = Labor manhours in Model I,

L_2 = percent yield loss in the appropriate USDA region for the production area in which the activity is defined,

L_3 = percent increase in machinery cost = 10 percent,

L_4 = percent increase in labor manhours = 20 percent,

R = percent of the infected wetlands that are replanted = 25 percent,

W = percent of wetlands in the production area,

I = percent of wetlands acres that are infected in the appropriate USDA region.

For the 75 percent of infected wetlands not replanted, it is assumed that 75 percent of these acres are treated in a rescue operation and 25 percent are not "rescued." Those acres not rescued have a 25 percent yield loss. Rescued acres have an additional cost of $2.14 (1963-65 dollars) per acre for the insecticides and have a 15 percent yield loss in addition to the rescue cost. The substitute chemicals are 50 percent

---

[1] See footnote on page 80.

effective in combatting these losses.[1] The equations used for the infected wetlands that are not replanted are:

$$\begin{pmatrix}\text{Yield loss if} \\ \text{not "rescued"} \\ \text{(bu. or tons)}\end{pmatrix} = Y_I \times L_5 \times R_N \times T_N \times W \times I \times S \qquad (5.5)$$

$$\begin{pmatrix}\text{Yield loss if} \\ \text{"rescued"} \\ \text{(bu. or tons)}\end{pmatrix} = Y_I \times L_6 \times R_N \times T \times W \times I \times S \qquad (5.6)$$

$$\begin{pmatrix}\text{Additional cost} \\ \text{due to rescue} \\ \text{operation}\end{pmatrix} = (\$2.14) \times R_N \times T \times W \times I \qquad (5.7)$$

where symbols are as previously defined and in addition:

L_5 = percent of yield loss if neither replanted nor "rescued" = 25 percent,

L_6 = percent yield loss if not replanted but "rescued" = 15 percent,

R_N = percent of infected wetlands not replanted = 75 percent,

T_N = percent of infected wetlands neither replanted nor "rescued" = 25 percent,

T = percent of infected wetlands not replanted but "rescued" = 75 percent.

Equations (5.1) through (5.7) are used to estimate the microeconomic effects of removing aldrin, dieldrin, chlordane, and heptachlor from the marketplace. These microeconomic effects are incorporated into the base model to form the insecticide restriction model; this model will be referred to as Model III, and Solution III as its optima.

Solution III

Removal of aldrin, dieldrin, chlordane, and heptachlor is shown by Model III to have few effects on U.S. agriculture in 1980. Evidently

---

[1] See footnote on page 80.

the areas and proportions of corn suffering losses and increases in costs are not large enough to have major effects on the national level of production (Table 37). Wheat productivity increases as acreage shifts between production areas. To produce the same output, wheat required 230,000 fewer acres in Solution III than in Solution I. Corn production requires 311,000 more acres to produce 18 million fewer bushels.

Based on the model's solution, estimated equilibrium prices and consumption show little or no change because of the insecticide restriction (Tables 38 and 39). Roughages experience the largest price increases (16 percent) because of yield losses and lower production.[1]

Per acre costs do increase with insecticide restrictions. However, crop production costs do not change greatly (Table 40). Costs of pesticide use increase nationwide by 13.4 percent, but total farm costs increase by only 0.6 percent. In the Corn Belt, one of the three USDA regions assumed affected by the insecticide ban, pesticide costs increase from $69 million in Solution I to $99 million in Solution III. Total costs in the Corn Belt increase by $20 million and cause a shift in land

---

[1]As mentioned previously, price levels are in terms of 1963-65 dollars. They would be higher if they were indexed to account for inflation since then. Also, prices reflect only variable costs in the supply relationships. While these conditions put prices below those expected in 1976, they apply similarly for comparison of prices and values within and between solutions for different models. Hence, the relative differences shown generally are of the same magnitude as if prices and values were expressed in terms of the value of the dollar in 1976 and if fixed costs also were reflected in all supply quantities.

Table 37. Estimated national acreages, production, and average yields of wheat, feed grains,[a] and soybeans for 1980, Solutions III and I compared

Crop	1980 Solution III			1980 Solution I		
	Acreage	Production	Ave. Yield	Acreage	Production	Ave. Yield
	(10^3 A.)	(10^6 bu.)	bu./A.	(10^3 bu.)	(10^6 bu.)	bu./A.
Wheat	41231	1519	37	41401	1519	37
Corn	47230	4208	89	46919	4226	90
Oats	11491	701	61	11497	701	61
Barley	20985	1014	48	20392	983	48
Grain sorghum	13422	759	57	13432	761	57
Soybeans	55862	1703	31	55753	1701	31

[a]Includes corn, oats, barley, and grain sorghum.

Table 38. Estimated national equilibrium prices, total domestic consumption, and per capita consumption for selected on-the-farm commodities, Solutions III and I compared

Commodity	1980 Solution III			1980 Solution I		
	Price[b]	Domestic Consumption	Per Capita Consumption	Price[b]	Domestic Consumption	Per Capita Consumption
	($/cwt.)	(mil. cwt.)	(lb.)	($/cwt.)	(mil. cwt.)	(lb.)
Cattle	27.3	449	196.1	27.3	449	196.1
Calves	19.4	2	0.8	19.4	2	0.8
Hogs	14.9	221	96.6	14.9	221	96.6
F. Milk	2.4	484	211.4	2.4	484	211.4
M. Milk	2.1	819	357.9	2.0	821	358.5
Oils	22.0	89	39.0	22.1	89	39.0
Sheep & lambs	21.8	12	5.2	21.8	12	5.2
Eggs[a]	20.8	61	26.6	20.7	61	26.6
Poultry	9.0	170	74.2	9.0	170	74.2
Cotton	21.5	39	17.0	21.5	39	17.0
	($/bu.)	(mil. bu.)	(bu.)	($/bu.)	(mil. bu.)	(bu.)
Wheat	1.30	486	2.1	1.30	486	2.1
Corn	.87	488	2.1	.86	488	2.1
Oats	.46	61	0.3	.46	61	0.3
Barley	.76	133	0.6	.76	133	0.6

[a]Unit on eggs is dozen to give the appropriate column units: ¢/doz., mil. doz., and doz.

[b]Weighted average of regional prices with production as weights. Measured in 1963-65 real dollars.

Table 39. Estimated national equilibrium prices of intermediate commodities for 1980, Solutions III and I compared

Commodity	Unit	1980 Sol. III	1980 Sol. I
		(dollars[a]/unit)	
Corn	bu.	0.87	0.86
Oats	bu.	0.46	0.46
Barley	bu.	0.76	0.76
Grain Sorghum	bu.	0.88	0.88
Oilmeal	cwt.	142.05	141.25
Soybeans	bu.	2.99	3.00
Roughages	ton	24.13	20.80
Feeder Calves[b]	head	147.41	147.10
Yearlings[c]	head	193.92	193.81

[a]1963-65 real dollars.

[b]400 pounds per head.

[c]700 pounds per head.

use within the region to less capital intensive areas. The Northeast and Appalachian regions experience cost increases, mainly in capital costs but pesticide costs do not change significantly.

On a national level, land use changes little under the insecticide limitation (Table 41). Of the three regions affected by the insecticide ban, the Northern Plains increased in crop acreage (500,000 acres). The amount of cropland in the Northeast and Appalachian regions also increases slightly. Cropland not used for crops for 1980 under Solution III is scattered throughout the Northern Plains, Lake States, and the Southeast (Figure 14).

Impacts of the insecticide restriction are greater at the regional level than at the national level (Table 42). Under Model III, 170,000

Table 40. Estimated national costs of crop production for 1980, Solutions III and I compared

Cost	National		Corn Belt[a]		Northeast[a]		Appalachian[a]	
	Sol. III	Sol. I	Sol. III	Sol. I	Sol. III	Sol. I	Sol. III	Sol. I
	(million dollars[b])							
Labor	1,534	1,527	487	487	66	64	71	69
Fertilizer[c]	1,732	1,734	749	750	65	62	103	99
Capital	8,807	8,742	2,675	2,653	407	398	491	478
Total	12,073	12,002	3,911	3,891	539	524	665	646
Pesticide[d]	280	247	99	69	5	5	14	14

[a]The Corn Belt, Northeast, and Appalachian regions are included because these are the three regions with significant changes between the two solutions.

[b]1963-65 real dollars.

[c]Fertilizer is a capital cost, but it is separated out in this study.

[d]Pesticide costs are included in capital costs, but are also separated for direct comparison.

Table 41. Estimated total cropland and cropland plus hayland available, acreage used and percent idle in 1980, Solutions III and I compared

Region[a]	Cropland				Cropland Plus Hayland			
	1980 Sol. III			1980 Sol. I	1980 Sol. III			1980 Sol. I
	Available	Used	% Idle	% Idle	Available	Used	% Idle	% Idle
	(1000 A.)				(1000 A.)			
NE	6,773	6,481	4.3	6.5	13,936	9,228	33.4	34.5
AP	11,622	6,839	41.2	43.6	16,899	9,112	46.1	47.8
SE	11,222	7,245	35.4	35.4	12,761	8,449	33.8	33.8
DL	11,517	10,443	9.3	6.9	13,288	11,835	10.9	8.8
CB	70,400	68,465	2.8	2.8	81,567	75,320	7.7	7.8
LK	27,147	21,860	19.5	19.5	35,972	30,847	14.3	14.3
NP	62,971	38,252	39.3	40.1	71,378	42,725	40.1	40.5
SP	31,692	27,736	12.5	12.5	34,947	28,827	17.5	17.5
MT	17,870	8,821	50.6	50.6	24,866	14,872	40.2	40.2
PC	9,785	9,372	4.2	4.2	13,415	11,587	13.6	13.6
US	260,998	205,514	21.3	21.5	319,028	242,850	23.9	24.0

[a] Region codes: NE, Northeast; AP, Appalachian; SE, Southeast, DL, Delta states; CB, Corn Belt; LK, Lake states; NP, Northern Plains; SP, Southern Plains; MT, Mountain states; PC, Pacific states.

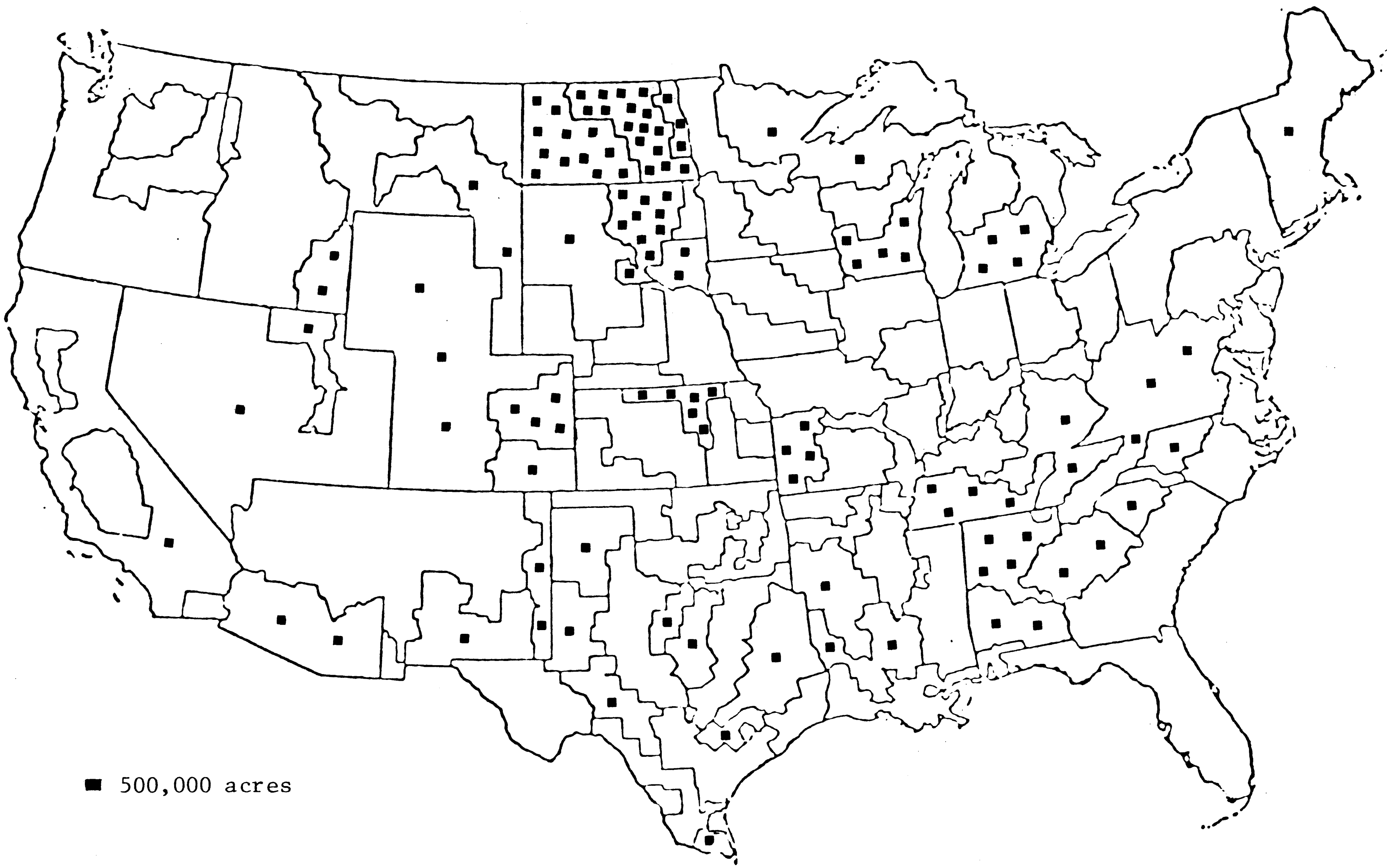


Figure 14. Unused cropland in 1980, Solution III

Table 42. Estimated acreage and production for 1980 of crops selected for significant changes, Solutions III and I compared

Region[a]	Wheat				Corn				Barley			
	Solution III		Solution I		Solution III		Solution I		Solution III		Solution I	
	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production
	(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 bushels)			
NE	2,248	95,515	2,435	103,422	713	56,437	527	38,911	2,492	149,634	2,343	140,650
AP	-	-	-	-	2,874	226,175	2,746	218,602	106	5,501	103	5,390
SE	-	-	-	-	321	188,045	3,212	188,045	30	1,223	30	1,223
DL	315	12,094	1,308	47,746	666	29,587	330	16,544	7	288	7	288
CB	4,209	197,562	3,449	161,895	26,647	2,680,809	26,984	2,733,929	444	22,709	445	22,698
LK	1,878	74,858	1,878	74,855	4,181	322,054	4,183	334,762	5,535	294,006	5,535	294,007
NP	7,915	244,201	7,666	216,277	6,253	478,139	6,253	478,330	4,429	201,762	3,987	179,618
SP	16,789	556,047	16,789	566,020	1,242	64,822	1,242	64,822	758	22,446	758	22,446
MT	1,428	53,516	1,428	53,516	737	85,141	737	85,165	6,407	279,366	6,407	279,363
PC	6,448	295,042	6,449	295,078	704	67,201	704	67,220	777	37,144	777	37,144
US	41,231	1,518,833	41,401	1,518,808	47,230	4,208,404	46,919	4,226,323	20,985	1,014,077	20,392	982,826

Region[a]	Soybeans				Roughages[b]			
	Solution III		Solution I		Solution III		Solution I	
	Acreage	Production	Acreage	Production	Acreage	Production	Acreage	Production
	(1,000 acres, 1,000 bushels)				(1,000 acres, 1,000 tons)			
NE	623	17,569	623	17,569	3,182	6,393	3,182	7,709
AP	2,719	82,575	2,579	79,240	2,589	5,111	2,586	5,921
SE	3,397	92,595	3,397	92,595	1,377	3,469	1,377	3,729
DL	4,059	109,834	3,702	99,505	1,497	3,334	1,498	3,461
CB	30,029	1,006,539	30,414	1,018,597	7,726	23,789	7,648	26,639
LK	6,168	149,314	6,171	149,402	11,512	31,425	11,486	37,277
NP	7,076	192,546	7,076	192,546	11,713	27,424	10,385	30,299
SP	1,791	51,590	1,791	51,590	2,010	10,465	2,011	10,468
MT	-	-	-	-	6,804	17,384	6,805	17,692
PC	-	-	-	-	2,778	13,679	2,777	13,674
US	55,864	1,702,552	55,753	1,701,034	51,188	142,473	49,753	156,867

[a]Region codes are identified in Table 41.

[b]Includes silage, hay, and wild hay.

fewer acres are required to produce the same amount of wheat as in Solution I. The Delta states decrease wheat production by almost 36 million bushels and one million acres. The Northeast region also decreases wheat production and acreage. These decreases are offset by increases in the Corn Belt and Northern Plains.

The relative advantage of corn in the Corn Belt declines and 337,000 acres shift out of the region. National corn production declines by only 18 million bushels, as acreage shifts to the Northeast, Appalchian, and Delta regions. Soybean production also shifts from the Corn Belt to the Appalachian and Delta regions.

While meat demand remains nearly constant (Table 38), barley becomes relatively cheaper as a feedstuff than corn; hence, barley production increases in the Northeast and Northern Plains regions. Nationally, roughage production decreases because of the increased costs of corn silage and so reduced demand by the livestock sector for corn silage. The relatively minor interregional shifts in production of wheat, feed grains, and soybeans are indicated in Figures 15, 16, and 17. Another indication of shifts in relative advantages in crop production are the changes in interregional shipments (Table 43). National and regional livestock production patterns change little due to the insecticide restriction (Table 44).

Farm Income and Consumer Food Costs

As with limitations on fertilizer, the insecticide restraint has only a modest impact on commodity prices, farm income, and consumer food

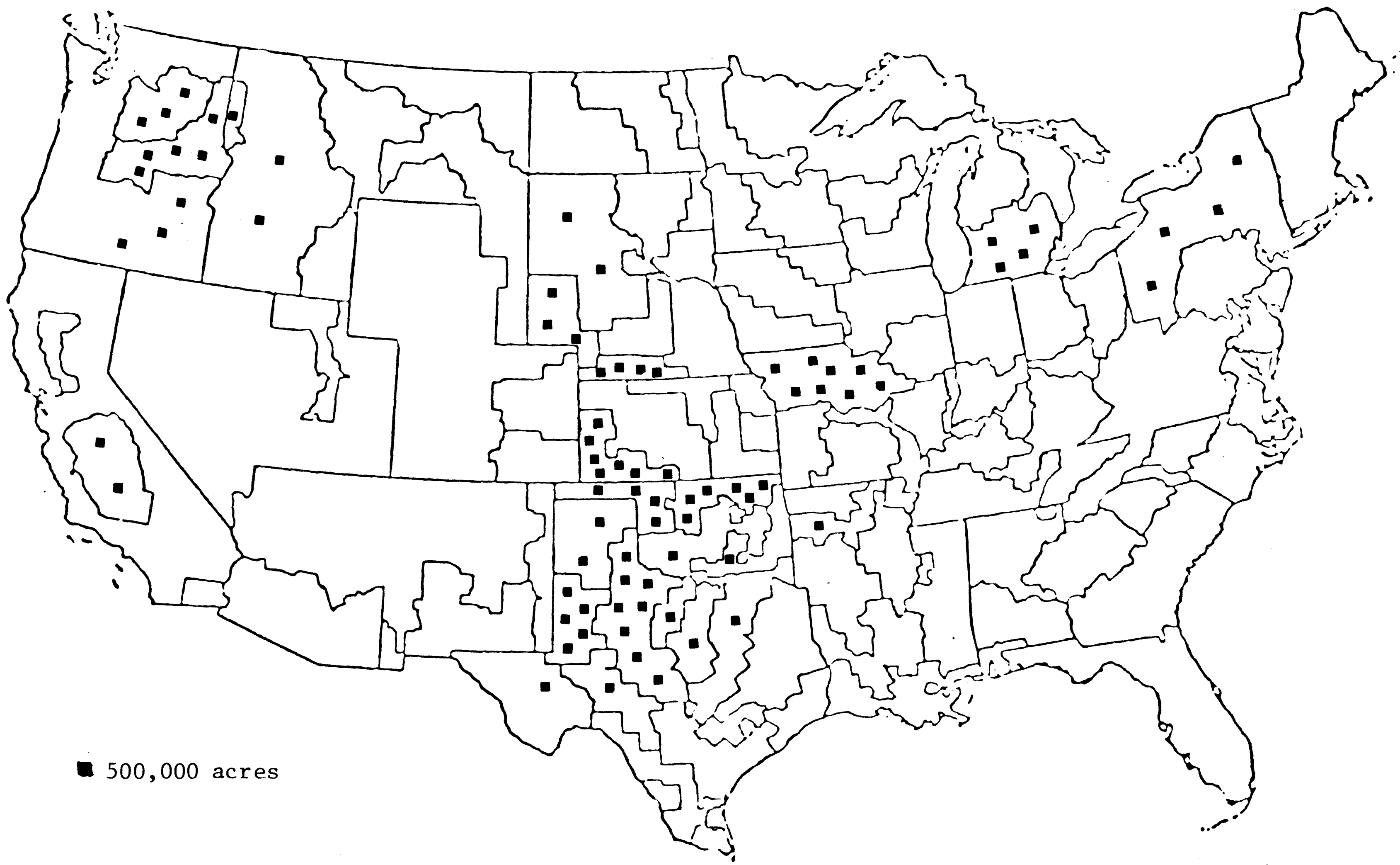


Figure 15. Acreages used in wheat production in 1980, Solution III

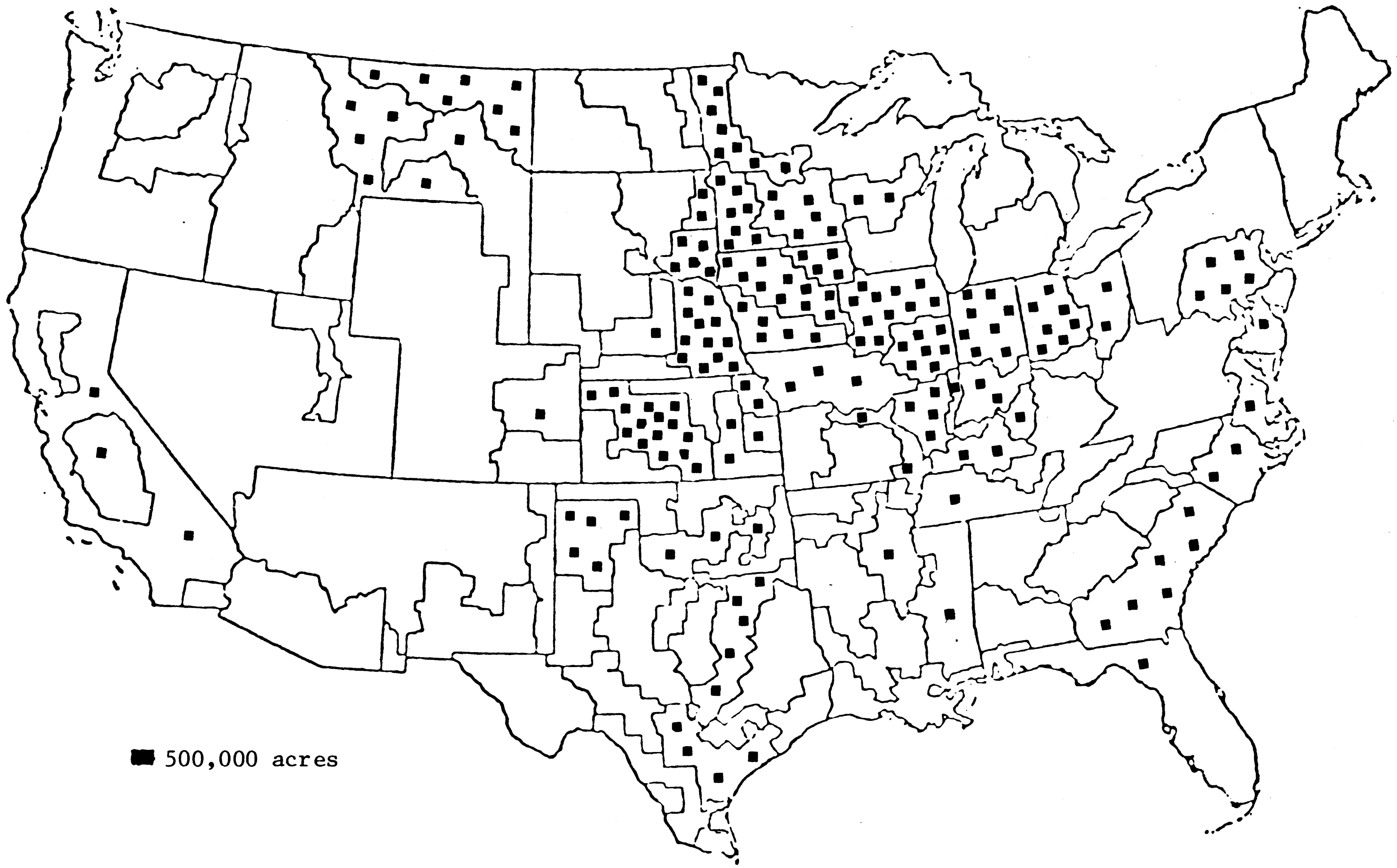


Figure 16. Acreages used in feed grain production in 1980, Solution III

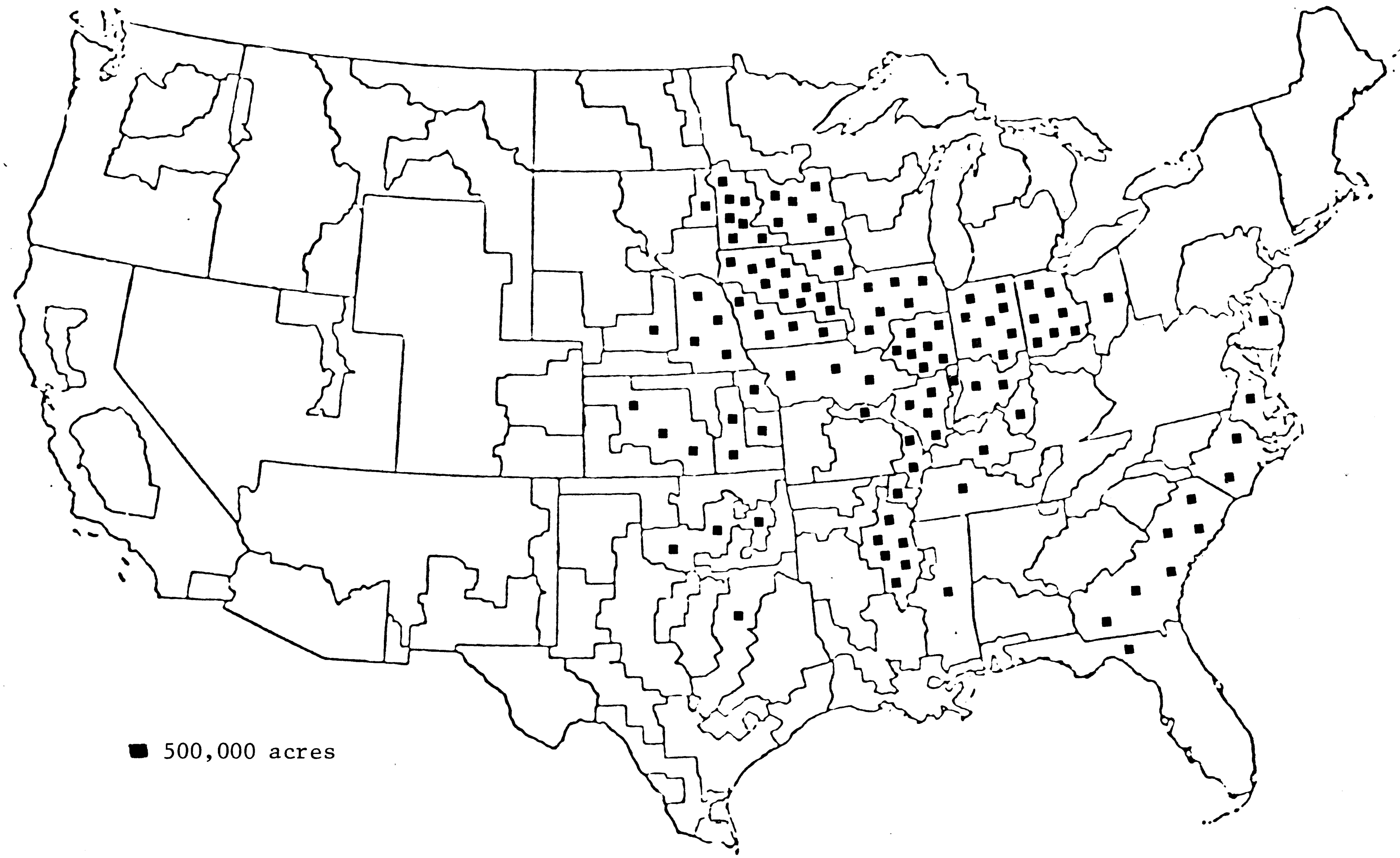


Figure 17. Acreages used in soybean production in 1980, Solution III

costs.[1] Value of production and farm-level consumer food costs for Solution III are compared with Solution I in Tables 45 and 46.

Table 43. Estimated interregional shipments[a] of wheat and corn for 1980, Solutions III and I compared

Region[b]	Wheat Sol. III	Wheat Sol. I	Corn Sol. III	Corn Sol. I
		(million bu.)		
NE	-96	-89	-108	-126
AP	-70	-70	0	-3
SE	-47	-47	-276	-276
DL	-242	-206	-761	-775
CB	92	56	1145	1179
LK	0	0	-145	-141
NP	213	205	145	141
SP	150	150	0	0
MT	0	0	0	0
PC	0	0	0	0

[a]Negative quantities are net imports; positive, net exports.

[b]Region codes are identified in Table 41.

Table 44. Estimated national livestock production for 1980, Solutions III and I compared

Livestock	1980 Solution III	1980 Solution I
	(1000 head)	
Beef cows	43,003	42,999
Milk cows	10,579	10,591
Fed cattle	28,911	28,916
Hogs[a]	219	219

[a]Hog unit is million live cwt.

[1]The qualifications mentioned earlier (i.e. footnote on page 86) relate to price and value quantities shown. However, the relative differences generally are the same is if all prices were converted to 1976 dollar values and fixed costs were incorporated.

Table 45. Estimated value of national production for selected commodities, Solutions III and I compared

Commodity	1980 Solution III	1985 Solution I
	(mil. 1963-65 dollars)	
Cattle & Calves	11,643	11,641
Hogs	3,254	3,252
Dairy	2,864	2,854
Wheat	1,978	1,935
Feed grains[a]	5,422	5,385
Soybeans	5,097	5,098
Sheep & Lamb	260	260
Eggs	1,264	1,262
Poultry	1,537	1,535

[a]Includes corn, oats, and barley for feed and food and grain sorghum for feed.

Table 46. Estimated total farm-level cost of desired commodities for consumers by region for 1980, Solutions III and I compared[a]

Region[b]	1980 Solution III	1980 Solution I
	(dollars[c])	
NE	118.91	118.81
AP	105.05	105.00
SE	102.30	102.19
DL	99.68	99.64
CB	110.47	110.40
LK	110.17	110.00
NP	101.68	101.57
SP	104.40	104.47
MT	105.47	105.40
PC	117.93	117.69
US	111.35	111.26

[a]Calculated from per capita consumption and regional price estimates.

[b]Region codes are identified in Table 41.

[c]1963-65 real dollars.

VI. SUMMARY AND CONCLUSIONS

This study evaluates the effects for 1980 of two possible policy alternatives that deal with potential environmental problems in U.S. agriculture. A quadratic programming model is developed to study the macro economic effects of government environmental control. Unlike linear programming, quadratic programming can optimize an objective function containing both linear and quadratic terms. This feature allows both the quantities demanded and the prices of the commodities to be determined simultaneously and endogenously to the model. Using Brandow's (1961) own and cross price elasticities, demand is expressed as a function of prices.

Three solutions are made reflecting three possible alternatives of environmental control. Solution I reflects U.S. agriculture in 1980 with no government imposed restrictions, payments, price supports, or other programs. Solution II estimates the impact of setting maximum rates of nitrogen fertilization on crops: 110 pounds of nitrogen on corn and sorghum (both grain and silage); 80 pounds of cotton; 55 pounds on wheat, oats, and barley; and no nitrogen on soybean. Solution III estimates the impact of removing four organochlorine insecticides (aldrin, dieldrin, chlordane, and heptachlor) from the market.

The effects on prices by the limited fertilization rate were more substantial than the effects by the insecticide removal. The largest price increase because of the removal of the organochlorines was for roughage, an increase of $3.33 per ton. This price increase was due to increased costs of roughage production as other acreages expand and push silage and hay onto less productive lands.

The nitrogen restriction caused small price increases in all commodities except soybeans and oil which declined in price. Lower yields resulting from lower fertilization rates together with lower but fairly constant domestic consumption cause less productive land to be used, production patterns to change, and prices to rise for all crops.

Price changes are modest under both the fertilizer and insecticide limitations because the export demand levels are modest compared to recent years. Hence, agriculture produces with a capacity that is large relative to domestic and foreign demands in the model. Agricultural supply prices are quite constant at this level of capacity and do not rise sharply until production pushes more tightly against capacity. If export demands were set at the levels of recent years, the price effects of the environmental restraints would be much greater. Hence, as further applications are made with the quadratic programming model developed for this study, evaluations need to be made with several different levels of export demands for 1980.

National production of commodities under the nitrogen restriction generally decreases in the face of higher prices. Corn production decreased by 276 million bushels. Per capita consumption of livestock remains fairly constant. Livestock demand for feedstuffs changes significantly because of the fertilizer limit. Use of barley in feeds more than doubles to 1,911 million bushels, while corn and grain sorghum use decreases.

Regionally, crop production patterns change because of relative shifts in comparative advantage under a feritlization limit. Wheat production decreases by 118 million bushels in the Corn Belt. Although part of this wheat acreage is shifted to corn, corn production still declines by 380 million bushels in the Corn Belt. Corn production in the Northeast, Mountain, and Pacific regions increases by 229, 36, and 7 million bushels, respectively. Other regions decrease corn production. The Appalachian and Northern Plains regions increase barley production by 47 and 336 million bushels, respectively, while the Northern Plains also increases oat production by 92 million bushels. Cotton production moves out of the Appalachian states and into the Southeast states while remaining in the Delta, Corn Belt, and Pacific regions.

Under the nitrogen restriction, wheat production shifts out of the Corn Belt. However, under the insecticide restriction wheat production in the Corn Belt is greater than under the nitrogen restriction or the base solution. Under the insecticide limitation, the Northern Plains increases wheat production by 8 million bushels while the Delta states decrease production by 36 million bushels. Corn acreage declines by 337,000 acres in the Corn Belt with the insecticide restraint and is replaced by wheat, however, corn production increases in the Northeast, Appalachian, and Delta regions. Barley production increases by 22 million bushels in the Northern Plains. Production of soybeans decreases in the Northern Plains, but increases in the Appalachian and Delta regions with the insecticide restraint.

The nitrogen restriction has a greater impact on production than does the insecticide restriction. Removal of the four organochlorine insecticides causes a higher total crop production cost. Both restrictions increase total crop production costs, but these increases come in different magnitudes. Under the fertilizer restriction, fertilizer costs decrease by $488 million, but labor and capital costs increase by $534 million for a net total increase of $46 million. Fertilizer costs decrease by $2 million under the insecticide restriction while labor and capital costs increase by $72 million for a net total increase of $71 million. Pesticide costs increase by $33 million because of the insecticide restriction and $30 million of this increase occurs in the Corn Belt.

The value of national production increases for all commodities except soybeans under the fertilizer restraint. Soybeans do not increase in value under the nitrogen restriction because of an excess supply of soybean oil.

Consumer food costs increase only slightly as the fertilizer and insecticide restrictions are applied. These food costs are based on changes in farm-level prices; it is assumed that processing costs would remain constant.

In conclusion: under the conditions of (a) normal trends in exports, and (b) absence of government programs of supply control and/or price support, either restriction on nitrogen or insecticide use could be applied with only slight increases in farm commodity prices and consumer food costs. Regional production patterns would be altered under either restriction with the nitrogen restriction giving the major changes.

As with all potential policies, there are certain trade-offs that must be remembered. Under the nitrogen restriction, more land is needed to meet domestic and export demands; these additional lands may be from the fragile land and marginal land areas. As an aggregate, more labor and capital are needed to produce, handle, and transport agricultural commodities. But in regions particularly dependent upon on high nitrogen usage for crop production, income and unemployment would decline. Similar impacts would occur under the insecticide limitation, although interregional shifts in production would not be as great as under the nitrogen limitation.

Costs and benefits of applying these policy alternatives would not be totally endogenous to agriculture. The suppliers of inputs and processors of output would also be affected as would the townspeople from the grocer to the teacher. Those in the areas of increased production would enjoy the benefits of more work and higher incomes, but where production drops, work and income both decline.

Nor would the costs and benefits be limited to the United States, alone. The question of decreasing potential food production is a much more sensitive question in today's world.

These are the types of trade-offs expected under many environmental and land use policies that are being proposed or legislated.

Limiting nitrogen and insecticide use may improve the quality of the environment, but it may come as a sacrifice of income and/or style of living by some people. This study has examined the economic effects of three potential environmental policy alternatives (restrict nitrogen use, restrict insecticide use, or do not restrict their use) but it is up to the U.S. people to examine the trade-offs and select the one alternative which prevails over others in net social gains.

CITED REFERENCES

Andrilenas, P.A.
1974
Farmers' use of pesticides in 1971...quantities. Agricultural Economic Report No. 252. U.S. Department of Agriculture, Economic Research Service, Washington, D.C., July.

Boot, J.C.G.
1964
Quadratic Programming. Chicago: Rand McNally & Co.

Brandow, G.E.
1961
Interrelations among demands for farm products and implications for control of market supply. Pennsylvania Agricultural Experiment Station Bulletin 680.

Brokken, R.F.
1965
Interregional competition in livestock and crop production in the United States: an application of spatial linear programming. Volumes 1 through 4. Unpublished Ph.D. dissertation, Ames; Iowa State University Library.

Chen, C.C.
1975
Quadratic Programming Models of U.S. Agriculture in 1980: With Alternative Levels of Grain Exports. Unpublished Ph.D. dissertation. Ames; Iowa State University Library.

Cottle, R.W.
1963
Symmetric dual quadratic programs. Quart. Appl. Math. 21: 237-243.

Cottle, R.W.
1964
Note on a fundamental theorem in quadratic programming. J. Soc. Indus. Appl. Math. 12: 663-665.

Cottle, R.W.
1966
Nonlinear programs with positively bounded Jacobians. J SIAM Appl. Math. 14: 147-157.

Cottle, R.W. and G.B. Danitzig
1967
Complementary pivot theories of mathematical programming. Technical Report 16. Stanford, Calif.: Stanford University.

Delvo, H.W.
1974
Economic Impact of Discontinuing Aldrin Use in Corn Production. ERS-557, U.S. Department of Agriculture, Economic Research Service, Washington, D.C.

Dorn, W.S.
1961
Self-dual quadratic programs, J. Soc. Indus. Appl. Math. 9: 51-54.

Eyvindson, R.H.
1970
A model of interregional competition in agriculture incorporating consuming regions, producing areas, farm size groups, and land classes. Volumes 1 through 5. Unpublished Ph.D. dissertation. Ames; Iowa State University Library.

Fuller, W.A., and J.E. Martin
1961
The effect of autocorrelated errors on the statistical estimation of distributed lag models. J. Farm Econ. 43: 71-82.

Goldman, A.J. and Tucker, A.W.
1956
Theory of Linear Programming. In Linear Inequalities and Related Systems, H.W. Kuhn and A.W. Tucker, editors, (Annals of Mathematics Study, no. 38). Princeton: Princeton University Press.

Hadley, G.
1964
Nonlinear and Dynamic Programming. Reading, Massachusetts: Addison-Wesley Publishing Co., Inc.

Hall, H.H.
1969
Efficiency in American Agriculture: An Application of Quadratic Programming. Unpublished Ph.D. dissertation. Ames: Iowa State University Library.

Hall, H.H., E.O. Heady, and Y. Plessner
1968
Quadratic Programming Solution of Competitive Equilibrium for U.S. Agriculture. American Journal of Agricultural Economics. Vol. 50.

Hall, H.H., E.O. Heady, A. Stoecker, and V.A. Sposito
1975
Spatial Equilibrium in U.S. Agriculture: A Quadratic Programming Analysis. J. Soc. Indus. Appl. Math. Vol. 17.

Hanson, M.A.
1961
A duality theorem in nonlinear programming with nonlinear constraints. Australian Journal of Statistics. Vol. 3, No. 2.

Hargett, N.L.
1974
1974 Fertilizer Summary Data. National Fertilizer Development Center. Tennessee Valley Authority. Muscle Shoals, Alabama.

Heady, E.O. and H.H. Hall
1968
Linear and Nonlinear Spatial Models for Agricultural Competition, Land Use, and Production Potential. American Journal of Agricultural Economics. Vol. 5, Dec. 1968.

Heady, E.O., H.C. Madsen, K.J. Nicol, and S.H. Hargrove
1972
Agricultural and Water Policies and the Environment: An Analysis of National Alternatives in Natural Resource Use, Food Supply Capacity and Environmental Quality, CARD Report No. 40T. Center for Agricultural and Rural Development, Iowa State University, Ames.

Ibach, D.B., and J.R. Adams
1968
Crop yield response to fertilizer in the United States USDA-SB 431.

Kuhn, H.W., and A.W. Tucker
1951
Nonlinear Programming. In (J. Neyman, ed.), Proceedings of the Second Symposium on Mathematical Statistics and Probability. Berkeley: University of California Press.

Learn, E.W.
1956
Estimating demand for livestock products at the farm level. J. Farm Economics 38: 1483-1491.

Meister, A.D., E.O. Heady, K.J. Nicol, and R. Strohbehn
1976
U.S. Agricultural Production in Relation to Alternative Water, Environmental, and Export Prices, CARD Report No. 65. Center for Agricultural and Rural Development, Iowa State University, Ames.

Metcalf, R.L.
1971
Pesticides. A Primer on Agricultural Pollution. Journal of Soil and Water Conservation. March-April.

Nagadevara, V.S., E.O. Heady, and K.J. Nicol
1975
Implications of Application of Soil Conservancy and Environmental Regulations in Iowa within a National Framework, CARD Report No. 57. Center for Agricultural and Rural Development, Iowa State University, Ames.

Nicol, K.J., E.O. Heady, and H.C. Madsen
1974
Models of Soil Loss, and Water Use, Spatial Agricultural Structure, and the Environment, CARD Report No. 49T. Center for Agricultural and Rural Development, Iowa State University, Ames.

Plessner, Y.
1965
Quadratic Programming Competitive Equilibrium Models for the U.S. Agriculture Sector. Unpublished Ph.D. dissertation. Ames; Iowa State University Library.

Plessner, Y., and E.O. Heady
1965
Competitive equilibrium solutions with quadratic programming, Metroeconomica, 17: 117-130.

Samuelson, P.A.
1952
Spatial price equilibrium and linear programming. American Economic Review. 42: 283-303.

Soults, D.J., J.J. Zrubek, and V.A. Sposito
1969
Zorilla, Reference Manual. Statistical Numerical Analysis and Data Processing Series, No. 9. Statistical Laboratory, Iowa State University, Ames.

Sposito, V.A.
1975
Linear and Nonlinear Programming, Ames; Iowa State University Press.

Stewart, B.A., Coordinator
1975
Control of Water Pollution from Cropland. Volume I, A manual for guideline development, Agricultural Research Service, U.S. Department of Agriculture; Office of Research and Development, Environmental Protection Agency, Washington, D.C., November.

Stoecker, A.L.
1974
A Quadratic Programming Model of United States Agriculture in 1980: Theory and Application. Unpublished Ph.D. dissertation. Iowa State University Library.

Takayama, T. and G.G. Judge
1964a
Spatial Equilibrium and Quadratic Programming. Journal of Farm Economics. 46: 67-93.

Takayama, T. and G.G. Judge
1964b
An Interregional Activity Analysis Model for the Agricultural Sector. Journal of Farm Economics. 46: 349-365.

Takayama, T. and G.G. Judge
1971
Spatial and Temporal Price and Allocation Models. Amsterdam: North-Holland Publishing Company.

Thompson, W.H.
1967
Transportation factors in marketing soybeans, cottonseed, and their products: 16 selected cooperatives. U.S. Department of Agriculture, Farmers Cooperative Service General Report No. 145.

Tucker, A.W.
1956
Dual Systems of Homogenous Linear Relations, in Linear Inequalities and Related Systems, H.W. Kuhn and A.W. Tucker, editors, (Annals of Mathematics Study, no. 38). Princeton: Princeton University Press.

U.S. Department of Agriculture
1967
Agricultural Statistics 1967, Washington, D.C.

U.S. Department of Agriculture
1972
Agricultural Statistics 1972, Washington, D.C.

U.S. Department of Agriculture
1973
Handbook of agricultural charts, 1973. Agricultural handbook No. 455, Washington, D.C.

U.S. Department of Agriculture
1974
Agricultural statistics, 1974. Washington, D.C.

U.S. Department of Agriculture, Economic Research Service
1964
Farm Income & States Estimates, 1949-1963. USDA FIS-195 (Supplement), August.

U.S. Department of Agriculture, Economic Research Service
1967
Feed statistics through 1966. USDA SB 410.

U.S. Department of Agriculture, Economic Research Service
1969
Supplement for 1969 to feed statistics. USDA Supplement for 1969 to SB 410.

U.S. Department of Agriculture, Economic Research Service
1971a
Supplement for 1969 to Food Consumption, Prices, Expenditures, USDA Supplement to AER 138, Washington, D.C.

U.S. Department of Agriculture, Economic Research Service
1971b
Farm Income: State estimates, 1949-1970. USDA, FIS-195 (Supplement), August.

U.S. Department of Agriculture, Economic Research Service and Statistical Reporting Service
1975
Livestock and Meat Statistics. Supplement for 1974. SB543. Washington, D.C.

U.S. Department of Commerce
1968
The economic base of selected geographic areas, historical and projected 1929 to 2020. Office of Business Economics, preliminary report to the Water Resources Council, Washington, D.C.

U.S. Department of Commerce
1975
Statistical Abstract of the United States, 1975. Bureau of the Census. Washington, D.C.

van de Panne, C. and A. Whinston
1965
The Simplex and the Dual Method for Quadratic Programming. Cowles Foundation Paper No. 221. Cowles Foundation for Research in Economics at Yale University. New Haven, Connecticut.

van de Panne, C. and A. Whinston
1969
The Symmetric Formulation of the Simplex Method for Quadratic Programming. Econometrica. 37: 507-527.

Wade, J.C., and E.O. Heady
1976
A National Model of Sediment and Water Quality: Various Impacts on American Agriculture, CARD Report No. 67. Center for Agricultural and Rural Development, Iowa State University, Ames.

Yaron, D., Y. Plessner, and E.O. Heady
1965
Competitive equilibrium - application of mathematical programming. Canadian Journal of Agricultural Economics, 13: 65-79.

ADDITIONAL COPIES of this publication are available by writing the Center for Agricultural and Rural Development, 578 East Hall, Iowa State University, Ames, Iowa 50011. Price is $3 per copy. A complete listing of all Center publications can be obtained free of charge by writing the same address.